television interference manual

by
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TELEVISION INTERFERENCE MANUAL

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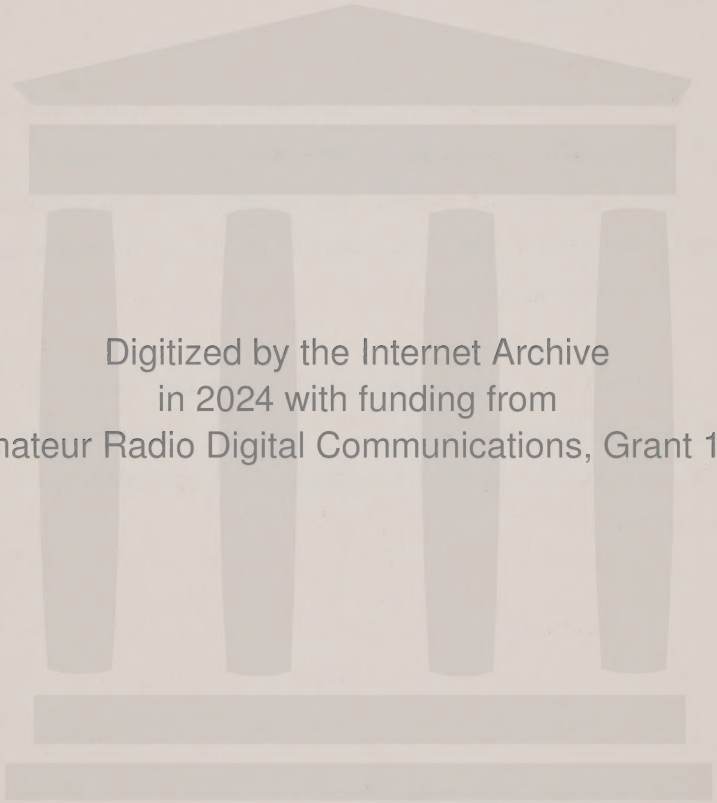
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CHAPTER 1

INTRODUCTION

Television interference is one of the most challenging problems in amateur radio, not because of technical intricacy, which is sometimes negligible, but due to the social difficulties created between the amateur and the viewer.

If a viewer experiences interference, his first reaction may be to assume this is due to a fault somewhere. A neighbour experiencing the same trouble will exonerate the television receivers in the viewers' eyes, and attention will be turned to the local amateur. If the amateur is contacted at this stage and can demonstrate his own clean screen,no tempers need be ruffled and the way is clear for cooperation in clearing the problem. If, however, the viewers temporarily defer action in the hope that the amateur soon clears the "fault" in his equipment, then blood pressure will rise as the interference continues until the eventual confrontation has all the makings of a major row. Even at this stage, if the amateur keeps calm and can prove his own tv is clean, peace can be restored, but on occasions the reaction has been violent.

In the context of tvi, the saying "if you wish for peace, prepare for war" has a lot to commend it. First of all realise that however expensive your equipment, it is not proof against maladjustment or component failure. Therefore, make quite sure you fully understand it, and keep a note of meter readings so you can detect any change in performance.

Secondly, to avoid trouble, any transmitter will normally require an external filter and precautions to avoid the injection of rf into the mains. Proving the effectiveness of these measures means a certain amount of careful testing whilst checking your own tv (the help of another amateur is useful here) but at the end of the checking procedure you can make the appropriate entry in your log knowing that you can demonstrate a clear screen and have acquired some experience of how to cure tvi.

At this stage it is not advisable to go round the district asking if you are causing interference. Firstly, you are likely to get the blame for faults of any type from then on, and secondly interference will be taken to mean deliberate jamming; talk about "breakthrough" if you have to, never "interference". The important thing is to appear reasonable so that complaints come to you while the viewer is still in a peaceable frame of mind. Exactly how you do this depends on you and your neighbours and the choice must depend on individual circumstances.

Now a few words about the Post Office. The Radio Interference Service is financed from tv licence revenue and is a service to the viewer, not the amateur. If a complaint is reported to them, the PO will try to locate the cause. If it is due to "in band" radiation from an amateur transmitter then the amateur is closed down till he can demonstrate to the interference officer that he has reduced the harmonic or spurious radiation sufficiently. If the fault lies with the tv and can be cured by a simple modification then the amateur may be closed down for 30 days to allow the modification to be made, ie the amateur is closed down either way. It is also Post Office policy to keep the amateur and complainant apart, presumably to prevent arguments. This means that the amateur is unable to help the interference officer who may not know of a defect in the particular tv which makes it susceptible to an amateur signal. The result could be that the amateur will be permanently closed down on the band in question. Clearly, calling in the Post Office involves delay and prevents the amateur making tests, except during a PO visit, when he is not allowed to see the result. Therefore, it is not recommended when it can be avoided. However, there are cases where some mediation is necessary and, in the absence of a local tvi group, the PO is the only body. In any case, amateurs should avoid aggravating the situation and then calling in the PO.

The official statement from the Ministry of Posts and Telecommunications concerning the procedure for investigation of interference is reproduced in appendix 11.

A local tvi group is the best solution. It consists of a few amateurs with some experience of the problem who have some suitable test gear (see appendix 12). Not being emotionally involved they are not inhibited from laying the blame fairly and squarely where it lies, be it a £300 colour tv or a £500 DX999 Super, but unlike the PO they go on from the fault to find the cure. This can be hard work, but the alternative is worse.

For many amateurs there is no tvi group locally, so it is a case of starting your own from scratch. Although the RAE is unique in covering the subject of interference, the newly fledged amateur often feels in need of more detailed guidance and the purpose of this book is to provide such assistance.

A lot of useful information has also been published in Radio Communication, RSGB Bulletin, Short Wave Magazine and QST. Back issues may be rather scarce, but can be borrowed through a local library from the National Lending Library of Science and Technology, Boston Spa. Where reference is made to material appearing in issues that may be difficult to obtain, the article, or an abridged version, is in many cases included as an appendix.

CHAPTER 2

TELEVISION CHANNELS, SYSTEMS AND TVI

Television is a wideband system and this is a major reason for tvi. Fig 2.1 shows the modulation bandwidth occupied by a 625 line colour channel. Any interfering signal in or near the channel may give trouble if it is sufficiently strong in relation to the television signal, but fortunately all frequencies are not equally potent. Obviously a carrier at A, near the sound carrier, will give audio interference and so this is one part of the channel highly susceptible to interference. However, if the same carrier were moved down in frequency to B, the audio beat frequently would pass beyond the limits of audibility, and the herring-bone pattern on the screen would be extremely fine so that the cathode ray tube could not resolve it. In this segment then we have a band of relatively safe frequencies where the television system is fairly insensitive to interference.

If the carrier is moved still further down in frequency the herring-bone pattern progressively becomes more and more coarse and easily visible as the vision carrier frequency is approached. The level of interfering carrier to give noticeable effect becomes less and less, till close to the vision carrier the threshold of tvi is some 50dB down on the television signal. When colour is being received, there is an additional sensitive area in the middle of the vision band at C, where the effect on a monochrome set is much less and could be completely undetected.

If the interfering signal is amplitude modulated its effects are more marked, since the slight fuzziness caused by a fine herring-bone will have edges. If the interference has key clicks or audio flat topping these will be sharp edges. Also a strong interfering signal may cause the television receiver agc to vary and make matters worse. Fm is the least visible, followed by A1 morse and then A3 and ssb.

A 405 line system has similar but reversed frequency bands. These are set out in fig 2.2 whilst fig 2.3 shows the corresponding standard intermediate frequencies, since interference due to radiation at i.f. particularly near 35MHz, is not uncommon. The effects of interference at i.f. are identical to that at the corresponding signal frequency but a slight adjustment of the television fine tune control will distinguish between the two. This will alter the i.f. slightly so that the herring-bone pattern will change if the interference is at i.f., but will make no difference if the interference is entering at the signal frequency. This can be a valuable clue in diagnosing tvi and the actual frequency of the interference can be found at the same time from the number of lines across the screen. This indicates the difference frequency in a similar way to a heterodyne beat note, see fig 2.4.

This type of interference can be caused by a transmitter with radiations in the television signal or i.f. bands. Clearly it is most important to reduce such radiation to a level which is negligible in one's own situation. Since tv field strengths vary tremendously with distance from the television transmitter and other factors, it is not practicable to lay down any hard and fast rules. but fig 2.5 indicates roughly how tv field strength and necessary harmonic suppression vary with distance from the tv station. A local group can of course draw on experience for a better estimate.

Unfortunately the greater proportion of tvi is due not to spurious radiations but to television deficiencies. The wide channels of television need low Q tuned circuits and so signals many megahertz away can enter the tuner together with the television signal. Due to the poor linearity of bipolar transistors an unwanted signal of 5mV is sufficient to modify the amplification of a wanted one in sympathy with its own modulation envelope. The result is that the modulation from an unwanted strong signal on 28MHz "crosses over" to the television signal on say 51.75MHz. In contrast to interference caused by spurious radiation tvi the interfering signal need not be in the tv band and the only cure is to reduce the level of unwanted signal reaching the television, often by a rejection filter at the television set. The use of frequency modulation is often successful in avoiding the problem by eliminating the modulation envelope but even here the click at the start and finish of each transmission will cause a disturbance on the screen. In extreme cases an unmodulated carrier can desensitize or block the television, resulting in a blank screen.

Sometimes the amateur signal enters the video or audio amplifier directly. As the video bandwidth is dc to 5.5MHz the 1.8 and 3.5MHz bands are the worse offenders, but any frequency, if strong enough,can make itself felt by rectification, even in the audio amplifier. These are again strong signal effects similar to cross modulation and again the cure is to attenuate the unwanted signal.

At one time many television sets had intermediate frequencies which covered the 14MHz band, or had second channel responses covering another amateur band. Although this problem is not strictly a large signal effect it can be cured by measures applicable to the latter.

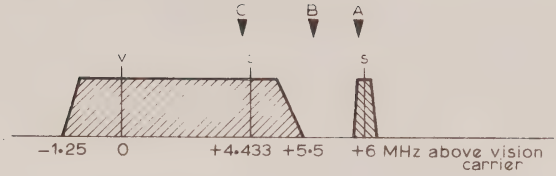


Fig 2.1. Sideband distribution of a 625 line television channel

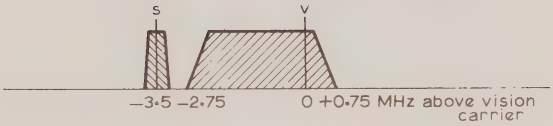


Fig 2.2. Sideband distribution of a 405 line television channel

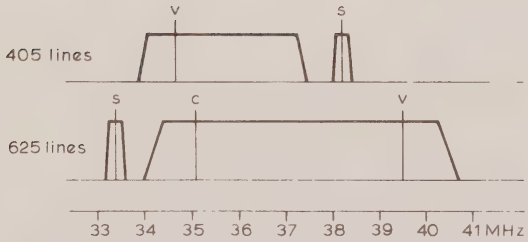


Fig 2.3. Sideband distribution of 405 and 625 line television channels after the mixer stage. As the local oscillator is on the high frequency side of the channel the spectrum is inverted

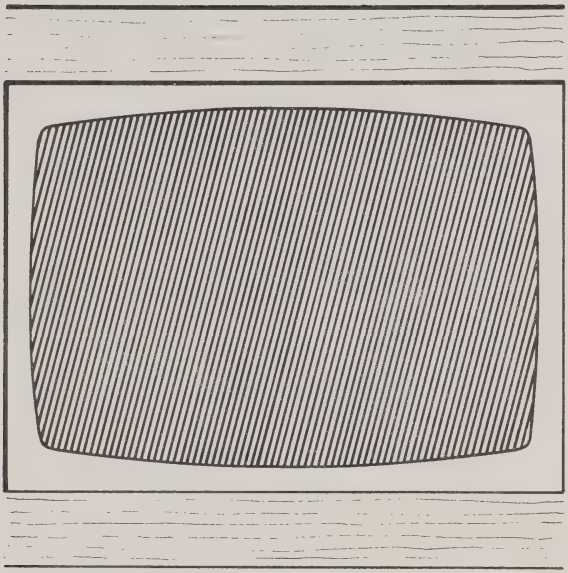
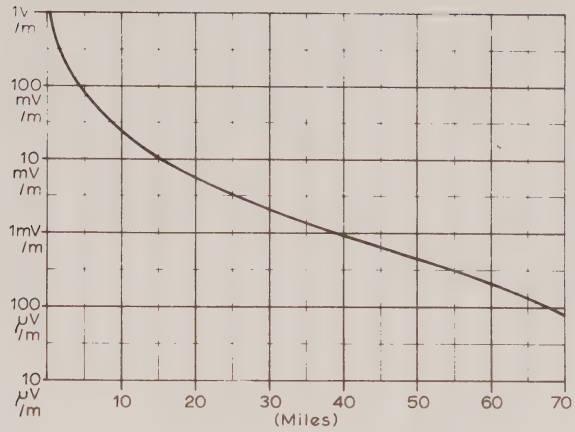
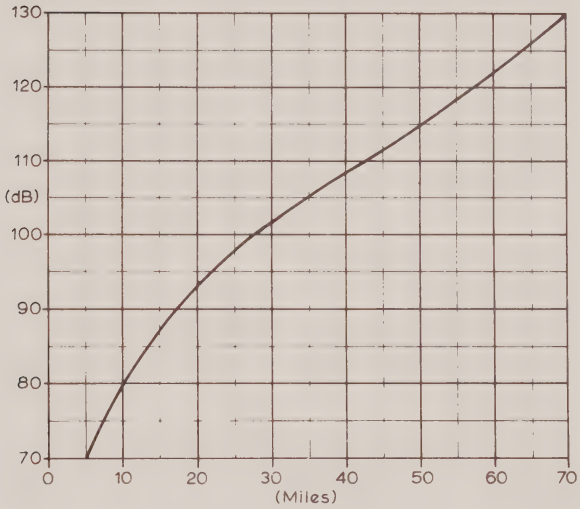


Fig 2.4. The approximate frequency of cw interference can be found from the herringbone pattern on the screen. Since the horizontal forward scan period is 80 or 50 microseconds for 405 or 625 lines respectively, the number of dark stripes counted straight across, divided by 80 or 50 gives the beat frequency in MHz



(a)



(b)

Fig 2.5. The approximate variation of field strength with distance from a main vhf transmitter is shown above. From this it is possible to calculate the corresponding variation of harmonic/spurious suppression needed by a 100W output transmitter, and this is shown in (b). These figures must only be treated as a guide prior to making tests, since it is not possible to allow for the variations due to aerial directivity or pitch of the herringbone pattern

CHAPTER 3

PRELIMINARY TESTS

It is important to realise that tvi is due to the transmitter/television system, so that a change in the aerial may raise the level of transmitter harmonic at the television receiver and necessitate more suppression at the transmitter. This is why it is particularly important to record fully the details of any tests and modifications. However, when starting from scratch the only thing to do is make an estimate of the situation and then make tests to confirm the extent of tvi and find out what improvements are necessary.

To illustrate the procedure, let us assume an amateur located somewhere in the Midlands is starting up with a W6PZV transmitter (ref.1). This should not be taken to imply that the W6PZV design is in any way faulty, indeed the design of some commercial equipments would not stand up to scrutiny anything like as well. The local television transmitters are on channels 4 and 8 and both are about 40 miles away. From fig 2.5 we see that the television field strength will be about 1 mV/metre and about 110dB of harmonic suppression will be needed in an average situation. Fig 8.7 shows that channel 4 is only in harmonic relationship with the top end of the 28MHz band, although other harmonics fall nearby and so could cause trouble if they are strong enough. Channel 8 is hardly likely to be troubled by the 13th harmonic of the 14MHz band if the harmonic filtering is adequate for channel 4.

In addition to harmonics there will be other spurious frequencies produced in the transmitter mixers, and some of these may give trouble. A first glance at the block diagram shows that the third harmonic of the 7MHz band crystal falls at 60MHz, in channel 4, while the 21MHz oscillator at 34MHz is in the television i.f. band. Further, detailed checking of the mixer outputs also shows up a third order product at 59 to 60MHz from the 21MHz band, (see chapter 8).

Products in the television channels will be attenuated by the low pass filter in the same way as harmonics and generally will be weaker if the transmitter drive levels are correct, so that normal harmonic suppression will be satisfactory. The 34MHz output is rather more of a problem since the low pass filter must work up to 29.7MHz and so cannot be expected to have maximum attenuation at 34MHz. One solution would be a low pass filter cutting off at about 25MHz for all bands except 28MHz, but probably the best solution is a 34MHz trap. This could consist of a 4.7pF capacitor and a slug tuned coil which resonate at 34MHz connected in series across the 21MHz coil, L9. Initially the trap can be temporarily short circuited, resonated to 34MHz with a grid dip oscillator, and the short

circuit then removed. At the same time it would be as well to check with the grid dip oscillator for any other spurious resonances in coils or chokes over the frequency ranges 30 to 70 and 170 to 220MHz which might boost unwanted frequencies. Any resonances found should be pushed out of the critical frequency bands by changing the l/c ratio slightly or by rewinding the coil with a greater number of turns spaced further apart (or vice versa) to keep the same inductance but alter the self resonance. Chokes are more difficult to manipulate, but even so judicious positioning near metalwork can give a slight shift which is easier than changing the choke.

As this is an area of weak television field strength the spurious radiation from transmitter leads is another probable cause of trouble, and so it is advisable to bypass every lead which comes out of the transmitter cabinet, not forgetting the vox leads and the microphone. Miniature disc ceramic capacitors will be adequate for most of the leads, and section 8.2 indicates that 560pF is a suitable value with a resonance about 60MHz with ¼in leads. The 700V rail requires a 1000V working capacitor, which has more inductance, and so a slightly lower capacitance is desirable to maintain near-resonant bypassing. In the case of the microphone lead a series 1000 ohm and 50pF bypass directly at the socket are desirable. At the same time the length of external leads should be checked in case they are close to resonant lengths at 60 or 34MHz. If long leads are essential screened pvc or rubber insulated wire can be used to reduce the radiation.

Having taken reasonable precautions against lead radiation we must now decide what type of low pass filter is needed. If the final amplifier is kept out of grid current we can expect the second harmonic to be some 30 to 40dB down (a pi-tank output would probably make this 40 to 50dB) so we need 70 to 80dB extra attenuation. If 15dB is allocated to the aerial matching unit then some 55 to 65dB seems desirable. The G5RV filter with an extra section will give 70dB so there should be some margin.

At this stage the transmitter may have adequate spurious radiation levels, but we must make tests to see if this is so, and if not, which bands and modes of operation are safe to use during television transmission hours. The arrangement shown in fig 3.1 is used to locate sources of lead radiation. Any spurious radiation induced in the search coil will cause interference to the television so that the search coil can be slowly moved about over the cabinet of the transmitter to find hot spots. This should be done on all bands and modes of modulation, until hot spots due to inadequate bypassing of leads or badly bonded cabinet seams are located. It is most important to realise that a little rf circulating on the outside of the cabinet may do no harm on dummy load but can cause serious tvi when an aerial is connected. It is, therefore, desirable to err on the stringent side.

Having passed this test the transmitter can then be tested on open

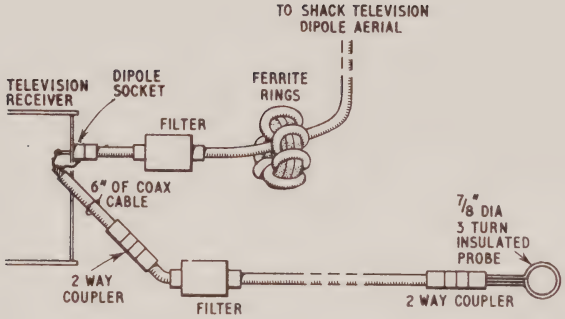


Fig 3.1. Search loop for detecting radiation in the television channel. The filters should reject the transmitter fundamental frequency so that there is no trace of interference with the loop about one yard from the transmitter. With some television sets no filters may be needed

aerial with the television back to its normal location. This will check the performance of the low pass filter but strong signal effects at the television can occur at the same time and may mask the presence of spurious outputs. For this reason the tests should be done with the television protected against overload with a braid filter and a high pass filter with considerable attenuation at the amateur bands in use.

Returning to our example, we know that potential trouble exists on 21MHz from the 34MHz and 59 to 60MHz spurii. Obviously the 34MHz output will be almost unmodulated so that a coarse herring-bone pattern seen immediately on switching on the transmitter will probably be this. If it were subsequently found that the beat frequency was about 600kHz independent of the transmitter vfo but variable with the television fine tuning (vision carrier i.f. is 34.65MHz) and that the interference could be substantially removed without loss of picture by a 35MHz wavetrap in the television feeder, then obviously this is the cause of the trouble. Probably slight adjustment of the trap across L9 would reduce the radiation further.

On the other hand the 59 to 60MHz spurious would show up as a fine herring-bone (vision carrier 61.75MHz) on modulation peaks or inserted carrier only. The pitch of the herring-bone would vary rapidly with the transmitter vfo, but not at all with the television fine tuner whilst a wave trap could only attenuate picture and interference simultaneously at about 60MHz.

Ten metres can be expected to give genuine harmonics on channel 4 and since the sound carrier is at 58.25MHz the transmitter should be set to half this frequency, ie 29.125MHz, to check the harmonic output.

By knowing the characteristics of various types of interference it is possible to decide what is happening and how to improve matters. It cannot be over emphasized that there is no one modification which is guaranteed to cure tvi. A good low pass filter may make little or no difference to harmonic tvi until the transmitter is properly screened and filtered. Even then the diodes in an swr bridge may give trouble by adding harmonics to the otherwise clean signal. Above all beware of the fallacy of assuming that a commercially produced transmitter cannot be at fault. A transmitter, like a television set, is a compromise between what is technically desirable and what the customer can afford. In an average situation a transmitter may only need the addition of a low pass filter but in a deep fringe area it is possible that the self same transmitter could not be made tvi proof without a complete rebuild, starting with the chassis. In most cases however, the first attempt at tvi proofing will be about 80% successful and the remaining bands or modes can be cleared by some more of the same treatment.

ref 1: filter type 100W output sidebander
J.Isaacs, QST November 1962, reprinted in the fourth and fifth editions of Single Sideband for the Radio Amateur (ARRL).

CHAPTER 4

FURTHER WORK

In the last chapter the process of testing a new transmitter installation was discussed. The result could be completely satisfactory on all bands, but on the other hand this is not certain. If tvi persists on some bands there are invariably further steps which can be taken. For instance, if the trouble is harmonic radiation, the low pass filter may need re-aligning, or a more elaborate filter capable of more attenuation, may be called for. Disc ceramic capacitors, although excellent in terms of value for money are poor lead filters compared with the devices described in chapter 8. Most cabinets have many holes for plugs and sockets, not to mention a seam round the lid approaching a quarter wave long at the tv frequencies. Ideally no hole in the cabinet should have a length in any direction exceeding ¼in. Achieving this may involve covering louvres with wire gauze, or adding extra screws. Meters are large holes to rf and so a shaped shield over the body of the meter is useful. Control shafts should pass through an earthed bushing in the panel, although wire wool can be used in lieu.

The search loop technique is invaluable in finding just where energy is leaking out of the transmitter cabinet, and in a fringe area time spent in this way will be well repaid.

In an area of good signal strength however, the first line of defence against spurious outputs may well be completely successful, and then attention is turned to the effects of a strong signal on the television.

Before dealing with television receiver overload, it is important to try and reduce this effect by measures at the transmitter. For instance, it is unreasonable to expect a television to reject many volts of rf produced by a transmitting aerial in the same loft as its own aerial. Also a transmitting aerial with radiation from the feeder is much more likely to inject a large fundamental signal into surrounding wiring or television feeders than one with no feeder radiation. There is little to choose between balanced or coaxial feeders provided they are installed correctly. Incidentally, feeder radiation can also raise the strength of harmonics reaching the tv aerial sufficiently to cause tvi.

As interference can enter the television set in any or all of five different routes, it is difficult to lay down any hard and fast rules, but the following ways are arranged in decreasing order of probability:

1. pickup on the television aerial

2. pickup on the television coaxial feeder

3. rf pickup on the mains lead of the television set

4. direct conduction through the mains/earth system from transmitter to television receiver

5. rf pickup on the wiring of the television

Dealing with these in turn, pickup on the television aerial can be attenuated by a filter rejecting the amateur band(s) concerned. Commercial high pass filters tend to have maximum attenuation over the 32 to 38MHz range and may give inadequate protection to bipolar transistor tuners. The design of high pass filters optimised for the amateur bands is covered in section 8.6.

In areas of high field strength of the television signal an attenuator may adequately protect the television set from overload by the amateur signal without excessively attenuating the desired signal. If the television was overloaded by the strong signal the attenuator can also improve the general picture quality.

In most houses the coaxial cable between television set and aerial is about 25 to 35feet long. It is therefore capable of acting as a reasonably efficient aerial for the hf amateur bands and because of the slope of the roof it will show little discrimination between horizontally and vertically polarised waves. This aerial is earthed at the lower end through a 470pF capacitor with a reactance of about 20 ohms at 14MHz and a mains lead of indeterminate length. The result is an appreciable voltage at the amateur frequency injected into the television. The cure is simply to prevent this injection either by allowing the induced current run to earth outside the television, or by adding a high impedance in series with the path through the television. One variant of the shunt to earth technique is to connect the outers of the vhf and uhf aerials together so that the television set is in the centre of what may be considered as a dipole. Remember that the centre of a full wave dipole is a high impedance point, so the technique is not infallible. Many types of braid filter have been devised to prevent the outside of the coaxial cable carrying rf dependent on the loss in television signal which can be tolerated. The technique involves a certain amount of detuning of the feeder aerial, and so the exact details and position of the braid filter can be found only by experiment.

Signals entering by routes three and four can both be reduced by mains filters at the television and transmitter respectively, but the problem may be aggravated by the aerial coupling system in use. If an end fed

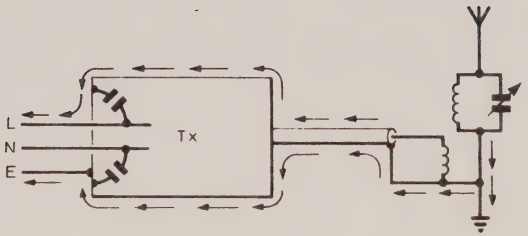


Fig 4.1. The direct connection between the rf earth and the coaxial cable allows some of the aerial current to flow to earth via the mains wiring. This is likely to cause overload of other equipment in the same house or block of flats

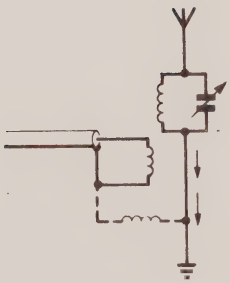


Fig 4.2. Separating the rf earth and the coaxial cable prevents the flow of aerial current into the mains. An rf choke with high impedance at the working frequency can be used to complete the circuit for 50Hz if it is necessary to use the rf earth as a safety earth

aerial is in use the system of fig 4.1 will use the whole mains and mains earth system as a counterpoise, particularly if the rf earth is high resistance. A change to the circuit of fig.4.2 will prevent this. If it is necessary to use the rf earth as a safety earth then a substantial rf choke can be interposed as shown.

Pickup on the television wiring is more likely on the vhf bands but certain sets have a resonance in the agc circuits which enhances 3.5MHz pick up. This is readily curable by adding a small choke. In general this sort of trouble is seldom met, which is fortunate as it can only be cured by modification to the set, which may be difficult socially even if the technical problem is slight.

CHAPTER 5

TRANSMITTER DESIGN

So far it has been assumed that the problem is due to an existing hf transmitter, although many points are also applicable to vhf equipment. When equipment is to be designed from scratch it is possible to reduce or eliminate some potential causes of tvi or make any necessary modifications without worrying about the resale value.

There are three cardinal rules for the design of clean transmitters:

(a) do not generate a frequency if you need not

(b) do not generate much if you have to

(c) do not radiate what you generate

Obviously the first thing is to decide which frequencies are likely to cause trouble in the particular location. For example in areas served by channels 2 and 9 the generation of 48MHz (and inevitably 192MHz) is not the safest way to get to 144MHz. A 72MHz oscillator would be much better, but in areas served by channel 13 and possibly 5, the converse would be true.

If the frequency of the oscillator was at 8MHz following by a string of multipliers, then all multiples of 8MHz will exist at some level. Having broken rule (a) then one must try and obey (b). Obviously in the 48MHz sensitive region the line up must be 8 - 24 - 72 - 144 to minimise the amount of 48MHz. Also a push-pull tripler stage from 24 to 72MHz will reduce the 48MHz output considerably. Further, reduction of the 48 and 192MHz components could be made by using semiconductors in the oscillator/multiplier section of the transmitter. This avoids the problems of screening a series of multipliers each dissipating several watts, without overheating. A neutralised pentode, such as an EF80, will amplify the clean output and incidentally add a little extra selectivity. In such a transmitter it would be very desirable to add a double tuned circuit (wide band coupler) after the 24MHz stage. This will attenuate the nearby 8MHz sidebands considerably when they are still spaced by one-third of the carrier frequency. Incidental advantages of the wideband coupler are the possibility of getting a flatter response over the working band for vfo operation (see fig 5.1) and better matching between stages.

In the case of an area served by channels 5 and 13 the line up could be 8 - 24 - 48 - 144 with a push push doubler from 24 to 48MHz.

Finally, having minimised the generation of the troublesome frequencies we must obey rule (c). Radiation from power supply leads is more troublesome at vhf and uhf than at hf so that better filtering than the ubiquitous ceramic disc capacitor is often necessary. However, the techniques are identical to those described in chapter 3.

Only tv channels 34, 52 and 53 are in direct harmonic relationship with the 145MHz band so that if the precautions described earlier are inadequate to reduce radiation from the aerial, an external low pass filter may not be the solution. A filter cutting off at about 160MHz can however significantly reduce outputs in band III, or in the 432MHz band, as well as harmonic tvi. Frequencies which lie below 145MHz such as 36, 48 or 96MHz will not be attenuated by a low pass filter, and in this case a band pass filter is necessary.

The design of a band pass filter is always a compromise between selectivity and insertion loss. If the transmitter has been designed with suitable double tuned circuits in the early stages the band pass filter need only have sufficient selectivity to attenuate frequencies at say ± 24MHz about 144MHz. This permits tighter coupling and reduced filter insertion loss, or a simpler filter. Suitable designs can be found in chapter 8.

Mixer spurious outputs have already been touched on in chapter 3. Briefly, when two frequencies f1 and f2 are fed into a mixer the output consists of an infinite number of products of the form nf1 ± mf2 where n and m are whole numbers 1, 2, 3, 4. Removing harmonics of f1 and f2 from the inputs does not prevent this although it may considerably reduce the level of some products. In general low order products, ie those with low values of m and n, have a greater amplitude than high order products but the relative levels depend critically on drive levels. For example, if f1 + f2 and f1 + 3f2 are considered the level of the first product will be proportional to the f2 drive level, but the other product will be proportional to the f2 drive level cubed. In other words, too high a drive level will cause the unwanted output to overtake the wanted output.

The frequencies of the unwanted products can be calculated and a method for simplifying the calculation is illustrated in chapter 8. Any such spurious frequency can be produced and often it is too close to the desired output to filter out if the frequencies chosen are in a simple ratio. For example if an attempt was made to heterodyne 7MHz with 14MHz then obviously 7 + 14 = 21 but also 2 x 14 - 7 = 21, 3 x 7 = 21, 3 x 14 - 3 x 7 = 21, 5 x 7 - 14 = 21, 4 x 14 - 5 x 7 = 21, 7 x 7 - 2 x 14..... etc. If the 7MHz were shifted to 7001kHz the resulting signals occur at 21,001, 20,999, 21,003, 20,997, 21,005, 20,995 and 21,007kHz - an impossible mess of signals. For this reason alone the frequencies should be chosen carefully, but the products can also fall in the tv bands. The design of some foreign

equipment is not ideal when viewed in this light, due to the unique UK television channels and i.f. band.

Fortunately mixer spurious products can be attenuated by filters if far enough removed from the desired output, and also, like certain harmonics in a multiplier, by balancing. There are four types of output product:

(a)	m odd	n odd	Generally the desired output f1 ± f2 is one of this class, other examples are 3f1 ± f2, 5f1 ± 3f2 etc.
(b)	m odd	n even	The most important member of this class is m = 1, n = 0 ie f1, others are f1 ± 2f2, 3f1 ± 2f2 etc.
(c)	m even	n odd	Similarly f2 (m = 0, n = 1) is the first member of this class.
(d)	m even	n even	Typically m = 2, n = 0 ie 2f1

A balanced mixer with two devices will suppress two of these classes of output by the balance ratio which can range from 20 to 40dB or more. Generally a balanced mixer will suppress the local oscillator output f2 and hence all other products in class (c). It may also suppress f1 and the other products in class (b), or it will suppress second harmonics like a push pull tripler and other products in class (d). With a four diode ring mixer it is possible to simultaneously balance classes (b), (c) and (d), but not all four diode mixers have this property.

It is clear that a combination of careful selection of the frequencies f1 and f2, effective filtering and balancing, unwanted mixer outputs can be reduced to negligible proportions in the same way as harmonics.

Finally, having produced the desired output frequency, either as ssb or cw, it must be amplified to the final power level. When doing this do follow handbook recommendations. A high l/c ratio in the grid or anode tank circuits may give a little more output, but a large part of the extra output will go into harmonics. The popular grounded grid linear amplifier in particular can produce a harmonic level which would shame a class **C** stage if not driven via a cathode tank circuit. A class AB1 linear can also produce serious harmonics (and splatter) if driven from a high impedance amplifier with little capacitance to preserve the waveform in the face of grid current peaks.

Parasitic oscillation must obviously be completely suppressed by neutralising and by vhf stoppers. Again, this subject is well covered in the standard text books.

The use of the pi-tank was first adopted as an anti-tvi measure by G5RV and has come to be almost the universal tank circuit. Since some published accounts of it are somewhat confusing it will be treated in some detail.

At a particular frequency a reactance and resistance in series are equivalent to another reactance and resistance in parallel. If the reactance is tuned out by another equal and opposite reactance the parallel resistance remains. This provides a means of transforming a load resistance of 50 ohms to say 2000 ohms at the anode of a valve and is known as the L network. Unfortunately the loaded Q of the circuit is determined by the resistance ratio, so that it is not possible to design for a particular circuit Q and optimum loading conditions simultaneously. The solution is to design an L network which places sufficient capacitance across the valve output for a Q of 12 and accept the odd value of load resistor resulting, and then design another L network to transform the actual 50 or 75 ohm load to this value, see fig.5.2. Obviously this circuit has the properties of a low pass pi-filter and so will attenuate harmonics more effectively than a conventional tank circuit up to the frequencies where the parasitic inductance of C1 and C2 become significant. Careful low inductance earthing of C2 in particular can make a large improvement in harmonic attenuation.

Unfortunately the pi-tank has little or no attenuation to frequencies lower than the desired one, and so should only be used after adequate low frequency selectivity. Also, as is clear from the design procedure, a pi-tank circuit will only work correctly into one particular load resistance, and even a small swr within a certain range of phase angles can result in damage to the tank circuit and/or power amplifier.

It is possible to change the phase of the load impedance by pruning the output coaxial cable and this can reduce the damaging effects of the swr. However, it is preferable to eliminate the swr completely by correctly matching the aerial or failing this to add a simple matching unit between feeder and transmitter so that at least the transmitter sees its correct load resistance.

The correct load resistance is also important to prevent damage to the aerial filter since the maximum voltage and current is multiplied by the value of swr. If a diode swr bridge is permanently installed this can produce sufficient harmonics to cause trouble in a fringe area, and so the system of fig 5.3 is recommended.

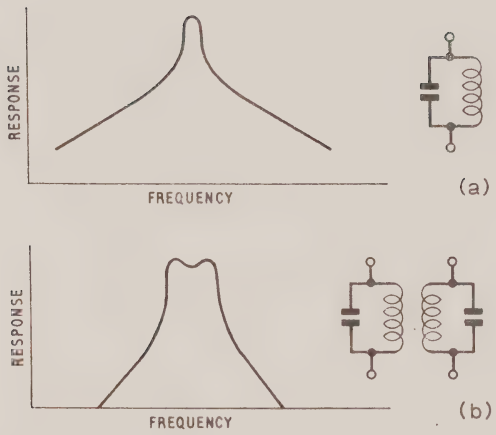


Fig 5.1. In a single tuned circuit the response falls at only 6dB/octave away from the resonant peak (a). When two coupled circuits are used the rate is 12dB octave

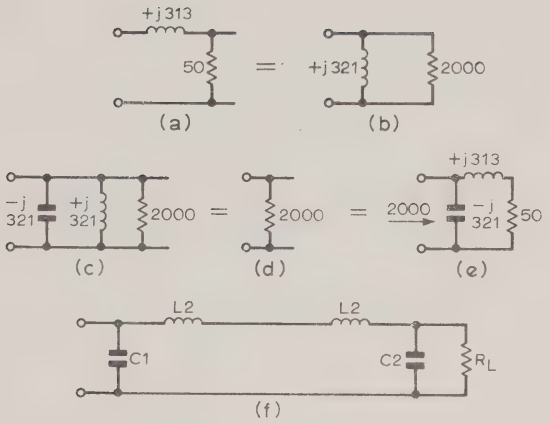


Fig 5.2. Evolution of the pi tank circuit. When a coil is connected in series with a 50ohm resistance (a) the result is equivalent to a much greater resistance in parallel with a coil (b). If this coil is tuned out (c) the result is just the high resistance (d). The complete L circuit is shown at (e). Two networks back to back permit C1 to be chosen for good loaded Q independent of the overall transformation ratio

Fig 5.3. Diodes in the swr bridge or power meter can generate sufficient harmonics to cause tvi in a fringe area. If the system shown is used such harmonics will be attenuated by the low pass filter and also any mismatch introduced by the filter will be monitored

CHAPTER 6

OTHER PROBLEMS

There are many ways in which television interference can be caused and some of these do not fall conveniently into the categories already dealt with. Although at least 90 per cent of all tvi is due to harmonic radiation or television overload, some reference to these more exotic forms is included for completeness. It cannot be over emphasised that ALL POSSIBLE PRECAUTIONS AGAINST SPURIOUS RADIATION AND TELEVISION OVERLOAD SHOULD BE TAKEN BEFORE LOOKING FOR SUCH AN EXPLANATION.

audio rectification

The base/emitter junction of a transistor, or the grid/cathode diode of a valve is capable of rectifying an rf signal applied to it. The detected modulation will then be amplified along with the desired signal and if sufficiently strong may cause serious interference.

Obviously the rf signal must have been received on some sort of aerial, often the outer braid of a television coaxial feeder. If the pickup can be reduced with a braid filter, as described in chapter 4 this is the best way to eliminate the problem. However, sometimes the rf field is so intense that wiring inside the set is sufficient aerial to give trouble. If the rf field cannot be reduced the offending amplifier must be modified.

If the trouble is occurring in the audio section of the television then a simple rc filter can adequately remove rf without affecting the audio bandwidth, see fig 6.1. If, however, the trouble is in a video amplifier with a 6MHz bandwidth, then it is not possible to filter out 1.8 or 3.5MHz rf without a serious effect on the response. Filtering must be confined to power supply and other non-critical leads acting as aerials. Frequency modulation and frequency shift keying are almost complete cures for this sort of tvi.

external rectification

Just as a manufactured diode in a swr bridge can produce harmonics from an otherwise pure signal, so can a natural diode formed by two conductors in contact, particularly when corroded. One case of tvi was traced to a nest of flying ants inside a trap aerial! Power rectifiers can also give trouble, but often external rectification is blamed for inadequate transmitter harmonic suppression. When the level of harmonic

output varies considerably with the state of the weather then it may be assumed that external rectification is at work. Nothing significant has been written on the subject since the article by M.Seybold, W2RYI, in the January 1953 issue of QST entitled "Harmonic radiation from external non-linear systems".

colour television interference

In general colour sets do not seem to be any more prone to interference at the signal frequency than monochrome receivers. There are two susceptible areas in the colour television which can suffer from interference.

Firstly, the colour sub-carrier i.f. is 35.066MHz. A 70.133MHz transmitter may radiate sufficient 35.066 signal to cause trouble, the cure is to reduce the radiation.

Also some sets are prone to interference at 3.5 to 3.8MHz upsetting the colour sub-carrier circuits at 4.433MHz. This generally yields to a braid filter, but in some cases the trouble is more difficult to remove and may vary as between receivers of the same type.

Some valve colour sets have appreciable radiation at harmonics of the colour sub-carrier (44.33 and 48.76MHz etc) which may cause interference for which the amateur is blamed.

masthead preamplifiers

Most masthead preamplifiers are basically a wideband amplifier covering 10 to 1000MHz. If they are not themselves driven into cross modulation by any strong signal within this range the amplified signal will probably cause cross modulation in the receiver. Some preamplifiers incorporate filters to reject out of band signals, and these give little trouble. Others which do not can be improved with external filters. In the event of trouble some manufacturers fit a uhf/vhf diplexer unit as a simple high pass filter between aerial and amplifier terminating the unused vhf output in 75 ohms, and this simple expedient is often highly successful.

communications receiver radiation

The local oscillator of a communications receiver can radiate harmonics at sufficient level to cause television interference in some areas. The national HRO is one offender due to the large signal level needed for the suppressor injection mixer, but some modern receivers also give trouble.

The same cures as for a transmitter are applicable. For information concerning the HRO, the principles of which are applicable to other valve receivers, see appendix 3,

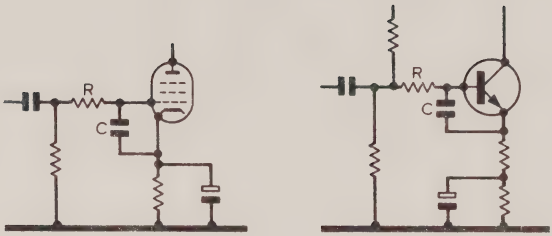


Fig 6.1. Adding a CR filter to an audio amplifier reduces the level of rf to below the threshold of detection without affecting the audio signal. Suggested values are R, 1kohm and C, 47pF, but in severe cases these values can be raised. In a transistor circuit the flow of bias current through R may upset the bias point if R is raised above about 560ohms, so it is preferable to increase C

CHAPTER 7

AUDIO BREAKTHROUGH

The purpose of this manual is to assist readers where problems arise from the use of television receivers in proximity to radio transmitters. However, there is an increasing number of cases where transmitting equipment is the source of interference to other electronic entertainment equipment such as audio amplifiers and tape recorders. In the interests of completeness a chapter is introduced which covers the basic problems involved.

Almost all audio equipment now being produced for the domestic market is entirely solid state and this switch from valves to transistors has coincided with a vast increase in hi-fi sales making it difficult to assess to what extent transistors are responsible for the increase in number of cases of interference. Certainly transistorised equipment appears to be far more susceptible to breakthrough than the older valve equipment. Also of significance is the now widespread usage of magnetic cartridges which require amplifier sensitivities of the order of three or four millivolts. This usually necessitates one or two additional stages of amplification compared with the older type of crystal and ceramic cartridges that have far higher outputs and therefore require far less gain from the amplifier.

Unlike television interference there is usually very little that can be done at the transmitter end to prevent the trouble, except the provision of efficient mains filtering. Apart from reducing power, moving aerials or switching off altogether, the cure must rest with the complainant. Like all kinds of interference this poses a social problem. The average cost of a stereo radiogram is around £80 to £100 and for a hi-fi installation comprising separate amplifier, speakers, turntable and possibly a vhf tuner the price rises to the region of £150 to £250. Any person having spent out this amount of cash is not going to take kindly to hearing a burst of cw or ssb coming through in the middle of a favourite record. Unfortunately telling your neighbour that it is not the fault of the transmitter, but his equipment, is not going to ease the matter, even though it is probably true. Of course each case has to be dealt with on its merits and no hard and fast rules can be laid down. Of prime importance is to use tact, patience and common sense. A special mention should be made here of the case of interference from an a.m. transmitter. Remember, your neighbour may well be receiving your transmission in full frequency stereo sound, and any adverse comments made about your neighbours is not likely to help the situation.

Causes

Before discussing the various ways in which the interference can be prevented it is necessary to understand how the rf signal reaches the amplifier and is rectified to emerge at the speaker as an unwanted signal. Fig 7.1 shows typical audio amplifier low signal stages and in the case of the transistor notice the base/emitter junction. This forms a pretty effective junction diode and any rf reaching this stage will be rectified and passed on as an audio signal to the following stages. Similar comments apply to the valve stage as rf reaching the grid of the valve is likely to be rectified and the resultant af signal passed on through the following stages as an audio signal. With the modern hi-fi amplifier having a high overall gain and an output rating of at least 10 to 15 watts per channel, rf breakthrough can be fairly dramatic.

There are a number of paths the rf signal can take to reach the circuitry of an audio amplifier. In high rf fields direct pickup by the equipment is possible. Normally however the signal is fed to the amplifier via one or more of the inter unit connecting leads. The more elaborate installations may have a tape deck, record player, fm and a.m. tuners, an amplifier and two or more speakers. These units are interconnected and in most cases the speakers are positioned some distance from the amplifier, via long leads. When such equipment is operated within a few hundred feet of an amateur station rf energy can reach the hi-fi installation to cause interference.

The most frequent path for rfi (radio frequency interference) is along the speaker leads. Usually the speaker is coupled to the amplifier by a two wire lead and these wires can act as an aerial to pick up the rf energy and feed it into the amplifier.

The first step is to find out which lead or leads are acting as aerials. Very often this is likely to be a matter of trial and error but there are a couple of ways in which identification of the offending lead may be revealed. Firstly with the af gain advanced the various signal carrying leads into the amplifier should be disconnected. If the interference stops or reduces then the lead concerned is to some extent acting as an aerial and will require attention as detailed later. Obviously the speaker leads and mains lead cannot be disconnected. A method can be tried that very often reveals which of these leads, if any, is causing the trouble. Couple a modulated grid dip oscillator or signal generator tightly to each lead and sweep the tuning dial back and forth. For best results the af gain control on the amplifier should be advanced so that the background noise of the amplifier can be heard from the speakers. If the lead being tested is conveying rf into the amplifier then an increase in background noise in the form of the modulating frequency will very often result when the oscillator is brought into close proximity to the lead. As amplifiers are very often

sensitive to certain bands of frequencies only it is essential that tests be carried out with the grid dip oscillator or signal generator tuned to the same frequency as that from which the interference is being experienced.

There are two basic ways of tackling interference in audio equipment. Either the circuit can be modified to prevent the rectification occurring or the rf energy can be prevented from reaching the amplifier circuitry by suitable rf bypasses or filters.

A suggested method of effecting a cure is first to bypass the speaker leads at the chassis with disc-ceramic capacitors from .001 to .02uF. The .001uF value would be used for vhf operation and the larger value for low frequency work. Be sure to bypass all speaker leads even though one lead may appear to be grounded. In many amplifiers there is a feedback tap at the ground side of the output transformer. In stubborn rfi cases it might help to use shielded speaker leads. If shielded cable is used it is usually earthed at both ends but it might help to leave the shield unearthed at the speaker end. This is because the equipment at each end of the connecting cable will always have some sort of return to a common earth, and connecting one shield at both ends completes a loop which often will respond to magnetic fields. There is no hard and fast rule however, and it is wise to try various combinations.

If you should find that the interference exists only on one band it might help to try different lengths of speaker leads because of probability that the lead is a resonant length on the band in question. Sometimes rerouting the speaker leads will eliminate the interference.

The second major path for rfi is via the ac mains cable. The mains wiring acts as an aerial in a strong rf field and so the rf is brought into the hi-fi units through the mains input cable. There are commercial filters available that can be installed between the mains socket and the equipment. Alternatively, a filter can be built using an rf choke wound on a ferrite rod together with bypass capacitors (.0001 to .01uF) from each side of the ac line to chassis ground. It cannot be over-emphasised that the greatest care is necessary in constructing ac mains filters including the use of capacitors of the correct type and rating.

Record players and tape decks

Record player tone-arm connection to the cartridge are usually made with small clips. The existence of a loose clip, particularly if oxidation is present, offers an excellent invitation to rfi. Also, the leads from the cartridge and those to the amplifier are sometimes resonant at vhf providing an excellent receiving antenna for rf. One cure for unwanted

.01 acrossspier terms — not w/ solid state/
won't work into capacitive load — High f osc —
Full power — destruction of output pwr module

rf pickup is to install ferrite beads, one on each cartridge lead. Check all connections for looseness or poor solder joints. Inferior connections can cause rectification and subsequent rfi.

Tape decks should be treated the same as turntables. Loose connections and bad solder joints all can cause trouble. Ferrite beads can be slipped over the leads to the recording and play-back pickup heads. Bypassing of the tone-arm or pickup leads is also effective, but sometimes it is difficult to install capacitors in the small area available. Disc capacitors (.001uF) should be used as close to the cartridge or pickup head as possible. Keep the capacitor leads as short as possible.

Preamplifiers

There are usually one or more preamplifiers used in a hi-fi amplifier. The inputs to these stages can be very susceptible to rfi. Fig 7.2 illustrates a typical preamplifier circuit. In this case the leads to the bases of the transistors are treated for rfi with ferrite beads by the addition of rfc2 and rfc4. This is a very effective method for stopping rfi when vhf energy is the source of the trouble.

Within the circuit of a solid state audio system, a common offender can be the emitter base junction of a transistor. This junction operates as a forward biased diode, with the bias set so that a change of base current with signal will produce a linear but amplified change in collector current. Should rf energy reach the junction, the bias could increase, causing nonlinear amplification and distortion as the result. If the rf level is high it can completely block (saturate) a transistor, causing a complete loss of any audible symptom. Therefore, it may be necessary to reduce the transmitter power output in order to pinpoint the particular transistor stage that is affected.

In addition to adding ferrite beads it may be necessary to bypass the base of the transistor to chassis ground, C1 and C2, fig 7.2. A suitable value is 100pF, and keep the leads short. As a general rule, the capacitor value should be as large as possible without degrading the high frequency response of the amplifier. Values up to .001uF can be used. The British Radio Corporation recently recommended a value of 2200pF for one of their transistorized radiograms. This effected a complete cure without affecting the fidelity of the amplifier. In severe cases, a series inductor rfc1 and rfc3 may be required whose value is 7 and 1.8uH, respectively. Fig 7.2 shows the correct placement for an inductor, bypass capacitor, and ferrite bead. Also, it might help to use a ferrite bead in the positive lead to the pre-amplifier stages rfc5 in fig 7.2. Keep in mind that fig 7.2 represents only one preamplifier of a stereo set. Both channels may require treatment.

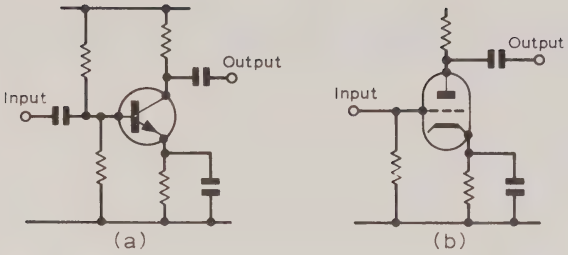


Fig 7.1

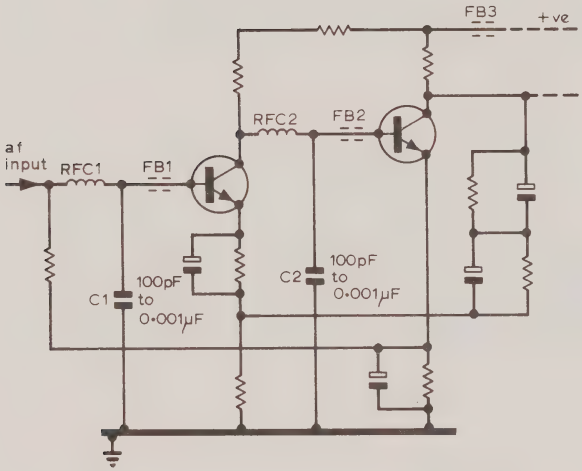


Fig 7.2

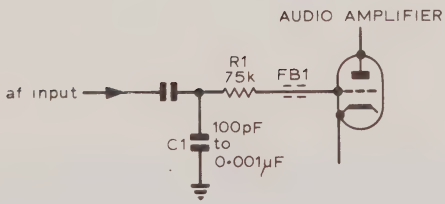


Fig 7.3

Similar treatment may be required in valve type amplifiers. Fig 7.3 shows an example of such a circuit with a series resistor, R1 and the bypassing recommended for a solid state unit.

In some cases it will be found necessary to fit bypass capacitors to more than one stage. An indication as to exactly where in the amplifier the rectification is taking place can be obtained by noting whether the level of the interference changes when the amplifier volume control is rotated. Similarly a test should be made to ascertain whether or not rotating the tone controls has any effect on the response of the interfering signal. If the signal is affected by adjustment by any one or all of the controls then the rectification is probably taking place in an earlier stage. The word "probably" is used deliberately, In a recent case investigation showed that the rf was getting past the first stage and being fed to the following stage via the volume control which was acting as a variable attenuator. Although the control affected the level of interference the rectification was taking place after the volume control.

In practice the fitting of bypass capacitors as shown in fig 7.2 usually results in a complete cure. Unfortunately this means working on the internal circuitry of the affected amplifier. This is fine if the amplifier is your own but be very careful before deciding to carry out any work on equipment belonging to a neighbour. It is best that this job be carried out by a serviceman. Not necessarily because the amateur involved is not capable of doing the work but because anything that subsequently goes wrong is likely to be blamed upon the amateur. If your neighbour does ask you if you would be prepared to carry out the work yourself think very carefully before you decide and if in doubt decline.

Fm tuners

There is often an fm tuner used in a hi-fi installation. Much of the interference to tuners is caused by fundamental overloading of the first stage (or stages) of the tuner, effected by the amateur's signal. The cure is the installation of a high pass filter, the same type used for tvi. The filter should be installed as close as possible to the aerial input of the tuner. The high pass filter will attenuate the amateur fundamental signal,thus preventing overloading of the front end.

Earthing

A few words regarding the earthing of amplifiers may be in order. Very often an amplifier will have a separate earth terminal at the back of the casing. It is sometimes recommended that earthing the amplifier to an earth separately from the mains earth by means of this terminal will help reduce rf breakthrough. Unfortunately the hi-fi installation is very

often so situated that a fairly long earth lead is necessary to reach the amplifier. Instead of providing an earth for rf signals it acts as an aerial and will sometimes increase the amount of break-through by increasing the rf energy present on the chassis. By all means try the effect of earthing the amplifier but also try disconnecting the earth lead if one is already fitted.

CHAPTER 8

DATA AND REFERENCE SECTION

Much of the essential information for curing tvi is scattered through many publications. The following collection lists both short pieces of information and reference to longer articles. In addition, details of some commercial products are included, but this does not imply that similar devices not mentioned are inferior. Information is not included on the relative susceptibility to tvi of transmitters or television sets, as a comprehensive survey has never been made. Whenever possible readers are advised to obtain equipment for a trial period and make suitable tests.

Information is arranged in alphabetical order, but without any cross references, so that information not found under a particular heading may be located under alternative description.

8.1 attenuators

Useful to reduce cross modulation where some loss of television signal is permissible. Also in an area very close to the television station, for reducing overload by the television signal.

Attenuators are generally 75 ohm devices made from standard carbon resistors. Commercial devices are available from R.S. Components, through dealers, with attenuation of 6, 12, or 18dB, fitted with Belling-Lee type coaxial plugs and sockets.

8.2 beads and chokes

A choke is a well known way of attenuating high frequency current. A cylindrical choke wound on an insulating former will be fairly effective near the frequency where it becomes parallel resonant with its stray capacity, but as the frequency increases it will go through a series resonance, then another parallel resonance and so on. The higher the Q, the lower the impedance at the series resonances. If the choke is wound on ferrite material, this has two advantages. First of all, less turns will be needed for the same inductance, so that the capacitance can be reduced, and secondly, the ferrite material can be chosen to become lossy above the first resonant frequency, so that the high Q series resonances do not occur.

In the extreme, one single turn round the ferrite may be sufficient, as with the well known anti parasitic beads, but even so it often pays

to try a few turns. Alternatively, six hole beads are available, which permit very close coupling between wire and ferrite when the wire is fed through the holes for two and a half turns. The same technique can be applied to mains leads, using either a ferrite rod or a ferrite ring of convenient size to avoid taking a soldering iron to a neighbour's television set.

beads: Mullard, FX1115 and FX1242;

R.S.Components, "anti-parasitic beads";

Neosid 0.159/0.079/0.197/F8.

chokes: R.S.Components, tv chokes;

Aladdin,

toroids: Mullard, FX1588

Neosid 4324R/1 F14A

six hole beads: Mullard, FX1898

Siemens B6152 series

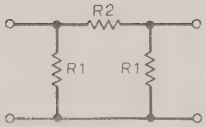
8.3 bypass capacitors and lead filters

All capacitors have series inductance which series resonates with their capacitance at some frequency, so that bypassing is particularly effective around this frequency. Mica and ceramic capacitors have low internal inductance, so that the resonant frequency is largely dependent on the lead inductance. This is not easy to control accurately, and so it is desirable to use the shortest lead lengths and large capacitance because in this way the resonance is broad and hence less critical.

Obviously, no leads at all would be better and so the capacitor manufacturers have produced bulkhead feedthrough capacitors, designed to act as a combination feedthrough insulator and bypass capacitor. These have a residual inductance of about 0.005uH.

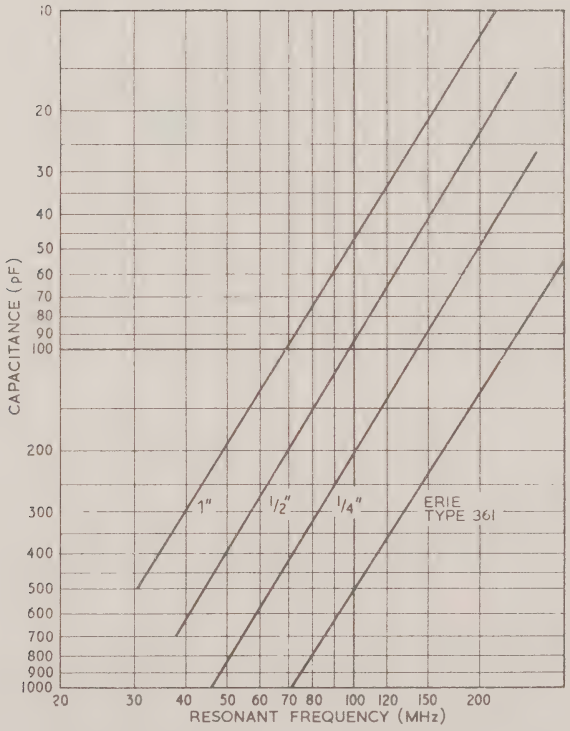
Similar devices are also met, with an integral ferrite bead, forming a complete bulkhead fitting filter. These are remarkably effective, although somewhat expensive, but a comparable effect could be got with a bulkhead capacitor and a separate bead.

ref: Bypassing for Harmonic Reduction. See Appendix 4
Grammer, QST April, 1951.



	R1	R2
10dB	150	120
15dB	120	220
20dB	100	390

Fig 8.1.1. 75ohm attenuators can be simply made with carbon resistors in a small tin box fitted with coaxial sockets



Self resonant frequency vs capacitance with various lead lengths for ceramic capacitors compared with a feed-through bypass

Fig 8.3.1.

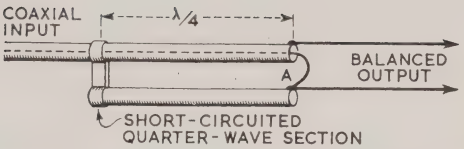


Fig 8.4.1. **Quarter-wave open balun or Pawsey stub.**

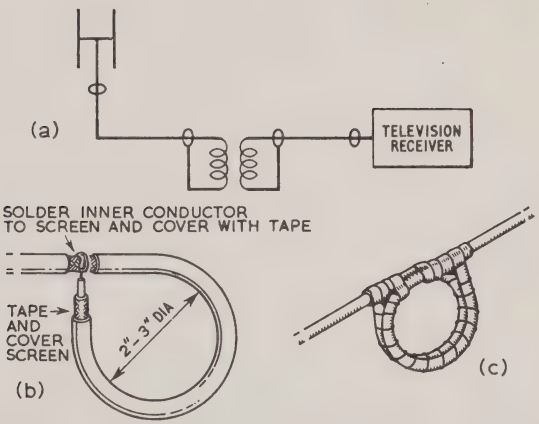


Fig 8.4.2.

Faraday double loop television receiver filter. (a) Basic arrangement of filter; (b) detail of one loop; (b) two identical loops are put together, taking care to insulate all wires/screens and taped or laced firmly.

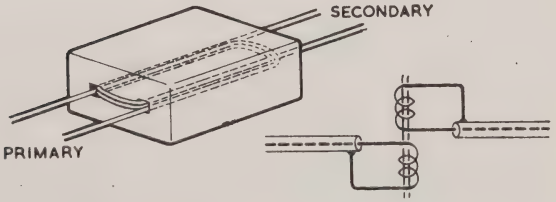


Fig 8.4.3.

Transformer for removing current from the outer braid of coaxial cable feeder. The primary and secondary are two turns of 24 swg enamelled wire on a TV balun core.

bulkhead capacitors: Erie type 361

R.S. Components, "lead-through ceramics"
(1000 pF, 350v dc working)

filters: Erie, CFT 3000

8.4 braid filters

In the correct mode of operation of coaxial cable, current flows along the inner conductor and returns along the inner surface of the outer. Provided the sheathing is thick enough, there is no current on its outer surface. At the receiver or transmitter this state of affairs can be maintained by completely enclosing the set in a metal box, so that nowhere can current flow from the inside, across a free end and on to the outside. At the aerial, problems arise, since an aerial enclosed in a screened box is not much use!

If the ends of the coaxial cable are simply opened out and fed into the centre of a dipole, similar to twin feeder, some received energy will flow on both inside and outside of the sheathing. Also, local interference may be picked up on the outside of the sheathing and flow up to the aerial and over onto the inside. On transmit, energy can be radiated from the outside of the sheathing, distorting the polar diagram, and possibly producing abnormally large voltages in surrounding television feeders or aerials.

These undesirable effects can be minimised with a balun, or balance to unbalance transformer. One simple form is shown in fig 8.4.1. An extra piece of coaxial cable is used to form a dummy twin feeder in conjunction with the outer of the main feeder. This neutralises the radiation as in any twin feeder system. The dummy feeder is short circuited to the main sheathing a quarter wavelength along, so that the twin feeder system presents a high impedance to the aerial and so absorbs little power. Off frequency it tends to tune out the aerial reactance, so the usable bandwidth may be increased somewhat.

This is one form of balun, others can be made with coils and capacitors or different lengths of feeder, and may act as an impedance step up or down, but in all cases the principle is to discourage current from flowing on the outside sheathing.

Sometimes one is faced with a situation where current has been allowed to flow on the outside, or the coaxial sheathing is neither thick enough nor solid enough to separate "inside" from "outside". Since few television sets are well screened the current will get inside again at the bottom and may cause tvi. One obvious solution is to bleed off the

outer current before it enters the television or to discourage the flow with a tuned trap or rf choke. Since there will almost certainly be standing waves on the outer, the best position for such devices can only be found by experiment. A pair of Faraday loops, or the G3BA transformer (see fig 8.4.3) break the path in a similar way but introduce loss of signal strength, and so cannot be used in a fringe area.

The system shown in fig 8.4.5 is an attempt to remove currents on the sheathing, but is based on a misunderstanding of the operation of coaxial cable, since currents on both surfaces of the sheathing are lumped together, it is not to be recommended.

In the absence of a balun, interference currents on the outside surface can also flow up to the aerial and back down the inside of the coaxial cable, so it is quite likely that a conventional filter will be required in addition to a braid filter.

Although mainly used on television receivers there is no reason why a ferrite core should not be used to prevent current flowing outside on a transmitter coaxial feeder due to say incomplete screening of the aerial matching unit.

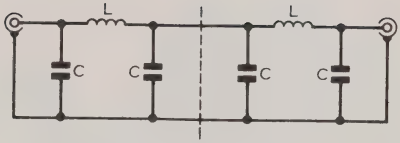
8.5 television channels

	Vision	Sound	
Band I			
1	45·0	41·5	1
2	51·75	48·25	2
3	56·75	53·25	3
4	61·75	58·25	4
5	66·75	63·25	5
Band III			
6	179·75	176·25	6
7	184·75	181·25	7
8	189·75	186·25	8
9	194·75	191·25	9
10	199·75	196·25	10
11	204·75	201·25	11
12	209·75	206·25	12
13	214·75	211·25	13
Band IV			
21	471·25	477·25	21
22	479·25	485·25	22
23	487·25	493·25	23
24	495·25	501·25	24
25	503·25	509·25	25
26	511·25	517·25	26
27	519·25	525·25	27
28	527·25	533·25	28
29	535·25	541·25	29
30	543·25	549·25	30
31	551·25	557·25	31
32	559·25	565·25	32
33	567·25	573·25	33
34	575·25	581·25	34

	Vision	Sound	
Band V			
39	615·25	621·25	39
40	623·25	629·25	40
41	631·25	637·25	41
42	639·25	645·25	42
43	647·25	653·25	43
44	655·25	661·25	44
45	663·25	669·25	45
46	671·25	677·25	46
47	679·25	685·25	47
48	687·25	693·25	48
49	695·25	701·25	49
50	703·25	709·25	50
51	711·25	717·25	51
52	719·25	725·25	52
53	727·25	733·25	53
54	735·25	741·25	54
55	743·25	749·25	55
56	751·25	757·25	56
57	759·25	765·25	57
58	767·25	773·25	58
59	775·25	781·25	59
60	783·25	789·25	60
61	791·25	797·25	61
62	799·25	805·25	62
63	807·25	813·25	63
64	815·25	821·25	64
65	823·25	829·25	65
66	831·25	837·25	66
67	839·25	845·25	67
68	847·25	853·25	68

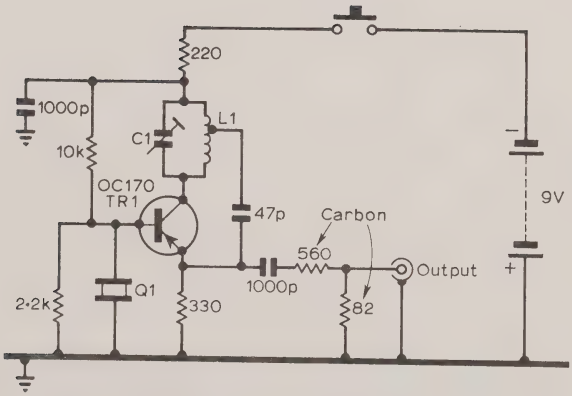
Toroidal filter

Fig 8.4.5. The wrong way to deal with pick up on a coaxial feeder



Band	C (pF)	L (μH)	Turns	Dia (inches)	TPI
3·5	820	2·3	12	1	8
7	500	1·0	11	5/8	8
14	220	0·55	10	1/2	8
21	150	0·37	7	5/8	4
28	110	0·28	5	5/8	4

Fig 8.6.1



C1 L1 to resonate at O/T frequency. Tap about ⅓ way down. TR1, OC170 or similar; x1, 3rd or 5th O/T. See Table 1

Fig 8.6.2.

Translated 625 line relay channels

Channel	Vision Carrier	Sound Carrier
A	45.75	51.75
B	53.75	59.75
C	61.75	67.75
D	175.25	181.25
E	183.25	189.25
F	191.25	197.25
G	199.25	205.25
H	207.25	213.25
J	215.25	221.25
RI	55.75	61.75

8.6 filters

A filter is a combination of coils and capacitors designed to pass certain frequencies and prevent the passage of others. Thus, in the pass band it behaves much like a length of coaxial cable. In particular it must be correctly terminated if the pass band loss is to be low. Most amateur filters are designed to work in 50 or 75 ohm coaxial cable. It is possible to scale a 75 ohm filter to 50 ohm without altering its frequency response by reducing all the impedance in the ratio 50:75, ie multiply all inductances by 2/3 and all capacitances by 3/2.

One exception is the so called half wave filter. This has the same property as a half wavelength of coaxial cable, ie whatever load impedance it sees is repeated faithfully at the input end, at its design frequency. As normally designed it is a low pass filter and can be used for 50 or 75 ohm systems indiscriminately. The snags are that it is strictly a one band device and the attenuation is not great. Details are shown in fig 8.6.1.

Clearly, this sort of filter is a low pass filter, since it will pass dc from output to input,but very high frequencies will tend to be short circuited by the parallel capacitors and impeded by the coils. In between there will be a gradually increasing attenuation with frequency. By either series tuning the capacitors, or parallel tuning the coils, a much sharper cut off is possible with a very large attenuation at the resonant frequency. Above the resonant frequency the attenuation is reduced. By carefully positioning the notches, a filter is designed to attenuate strongly over a required band of frequencies, and yet have a

low swr in the pass band, it follows from this that a filter should be designed to have its notches where they are most useful, and should then be set up as accurately as possible. Failure to do this can degrade the performance by 20dB or more.

A grid dip oscillator is useful for initial setting up, but is not sufficiently accurate if maximum attenuation is to be achieved. The expedient of setting up a low pass filter in the television set coaxial cable is not recommended. Firstly, the television set will often receive a fair signal on its unscreened wiring and secondly, it is not possible to notch out precisely that part of the television channel where harmonics fall.

An accurate signal generator is not always available, so the device shown in fig 8.6.2 and 3 was designed. This is a crystal controlled generator used in conjunction with a television set to set up the filter for minimum interference. The oscillator is built with its battery in a diecast box with only the output socket and press switch extending outside the box to reduce radiation. Even so, some interference is being deliberately radiated via the television aerial so that tests should be of the shortest possible duration and then only during television test transmissions. Adjusting the filter for minimum interference with the television should put the notches at the correct frequency or very close, but it may be useful to do a final slight adjustment after the filter is finally installed at the transmitter.

A high pass filter can be derived from a low pass by replacing all capacitors with inductors and vice versa. If this is done systematically the impedance and cut off frequency are unchanged, but the attenuation characteristic is inverted eg if the cut off frequency were 30MHz, a notch at 60MHz (2 x fc) becomes a notch at 15MHz ($\frac{1}{2}$fc) and indeed all the characteristics of a high pass filter can be derived from a low pass prototype in this way.

It is thus equally important to align a high pass filter, but since the transmitter is generally the unwanted signal, a special generator is not necessary.

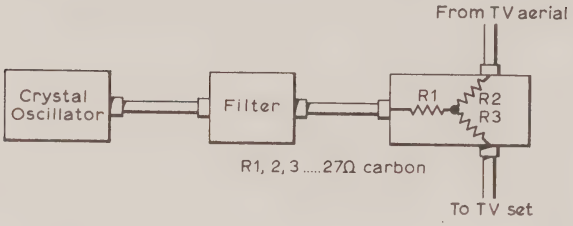
The same basic design of filter in fig 8.6.4 is useful at two frequencies and impedance levels. The G5RV filter and the 50 ohm version have a cut off frequency about 34MHz and deep notches at 42.5MHz. It is recommended that air spaced variable capacitors are used for C1 and C4 to permit accurate setting up of these notches with the alignment generator.

If alignment of the coils with a gdo has to be relied upon, the following procedure can be used:

Fig 8.6.3.

Table 1. Suggested crystal frequencies

Channel 1	42·5MHz
Channel 2	50·0MHz
Channel 3	56·75MHz
Channel 4	58·25MHz (Sound channel)
Channel 5	63·25MHz (Sound channel)



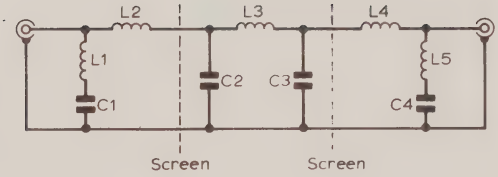


Fig 8.6.4. 80ohm pass filter

C1 C4 36pF 5% 750V mica (see text)
C2 C3 120pF
L1 L5 0.36 uH 7t 16swg ½in dia. 1in long 1in lead
L2 L4 0.59 uH 10t " " " "
L3 0.73 uH 12t " " 1in long 1in lead

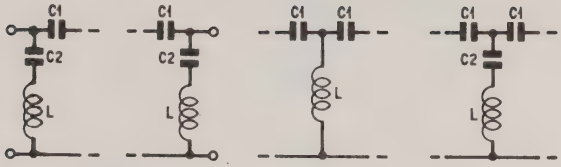
50ohm low pass filter

C1 C4 56pF 5% 750V mica (see text)
C2 C3 180pF
L1 L5 0.25 uH 6t 16swg ½in dia. ¾in long 1in lead
L2 L4 0.37 uH 7t " " 1in "
L3 0.46 uH 8t " " " "

144MHz 75ohm low pass filter

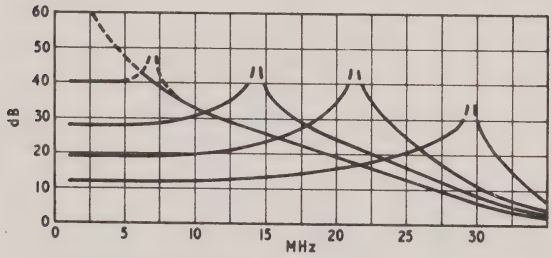
C1 C4 8.2pF (see text)
C2 C3 27pF feedthrough bypass
L1 L5 0.0825 uH 4t 18swg ¼in dia. ½in long ¼in leads
L2 L4 0.124 uH 4t 18swg 5/16in dia. ½in long ¼in leads
L3 0.155 uH 5t 18swg 5/16in dia. 3/8in long ¼in leads

Fig 8.6.5.



	HALF-SECTION	CONSTANT K	28 MHz	21 MHz	14 MHz	7 MHz
C1	98·5pF	54pF	98·5pF	74pF	64pF	60pF
C2	53pF	——	107pF	300pF	700pF	3000pF
L	0·55μH	0·16μH	0·28μH	0·21μH	0·18μH	0·17μH
TURNS	10	3½	5½	4	4	4

INTERNAL DIA ½" ..... WOUND ON WHITWORTH BOLT WITH 16 SWG WIRE



"Building Blocks" for tailoring a filter for a particular situation.

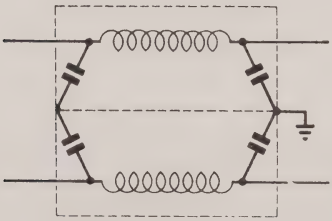


Fig 8.9.1. A typical rf filter for insertion in mains supply lead. Capacitors should be from 400 to 2000pF, at least 750V rating, and preferably designed for this specific purpose. The coils consist of a quarter wavelength of 16swg wire at the centre of the television channel (69in for Ch 1, 46in for Ch 5) wound on a 1in diameter former

with the coaxial socket short circuited and L2 removed L1 C1 should resonate at 42.5MHz. With L4 removed L5 C4 should also resonate at 42.5MHz. Still with short circuits L2 C2 and L4 C4 resonate at 19MHz without L3. With L2 and L4 removed L3 C2 C4 resonate at 24MHz.

To minimise unwanted coupling, coils should be mounted with their axes at right angles, and capacitors earthed with the shortest possible leads direct to the case.

The 144MHz version has a cut off frequency of 154MHz and notches at 193MHz to attenuate the fourth harmonic of 48MHz. The alignment frequencies are 193MHz in place of 42.5, 87 in place of 19 and 109 in place of 34MHz. Because most ordinary capacitors have too much inductance it is recommended that C2 and C3 are feedthrough bypass capacitors of appropriate value, mounted through the screens.

When carefully made, with good quality components and correctly setup the 24MHz filters can realise 90dB attenuation at the notch frequency, and a minimum of 55dB up to 100MHz.

It is not easy to produce the same notch attenuation at vhf, due to component losses, but with care a very useful degree of attenuation can be obtained.

Band pass filters, as their name implies, pass a band of frequencies and attenuate frequencies above and below the pass band. They are made up of one or more tuned circuits resonating in the pass band. The tuned circuit Q required is much greater than for a high or low pass, and increases as the pass band is made narrower. For this reason a low loss band pass filter is most practical at vhf in the form of a transmission line filter. At 70MHz, and to some extent at 144MHz, a coaxial line is rather bulky, but can be made shorter with capacitive loading, or even be folded. Another possibility in this frequency range is the helical resonator.

ref: (1) Radio Communication Handbook, RSGB
(2) VHF/UHF Manual, RSGB
(3) Radio Amateurs' VHF Manual, ARRL
(4) Simplified Modern Filter Design by P.R.Geffe,Iliffe
(5) Which Filter? Radio Communication, July 1969
(6) Handbook of filter synthesis by Zverev, Wiley.
(useful practical information on helical filters)

commercial filters

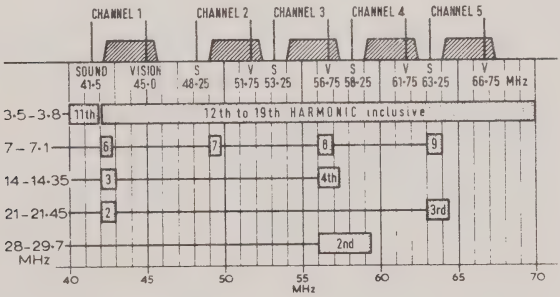
Burns FL2 and FL4 VHF low pass filters for transmitters

Pye	AGO 6994	VHF notch filter for protecting television sets. When slug is freed with methylated spirit, the notch can be peaked at 145MHz with a rejection of about 30dB.
TCC	263 and	
Belling Lee	L1425	Similar to GPO 38A.

Post Office filters

35A Dual bandpass 40 - 70MHz and 170-220MHz
38A High pass filter, cut off 40MHz but maximum attenuation at 32 - 38MHz. May cause appreciable loss in uhf bands.
48/1A)
48/2A) Tunable notch filters covering 35 - 50, 45 - 100 and
48/3A) 110 - 220MHz respectively.
49A Tunable braid filter, 16 - 40MHz

8.7 harmonic relationship



Harmonic relationship between the amateur bands and tv channels in Band 1.

8.8 harmonic indicator

A sensitive and preferably portable instrument can be useful for making checks on a transmitter, or locating a rectifying joint. The average transistorised television field strength meter is as prone to overload as a transistorised television set and so needs protecting with filters and screening if the readings are to be meaningful. The device described in the reference following is housed in a metal box and uses valves.

Ref: A sensitive harmonic indicator, J. W. Mathews, G6LL, RSGB Bulletin, May 1961.

8.9 mains filters

As an alternative to the chokes described in 8.2 an effective choke can be made by winding two quarter wave lengths of 16 swg (1.6mm) enamelled wire on one inch formers and assembling the filter in a metal box as in fig 8.9.1. Ferrite rods can be used as formers, when fewer turns are sufficient, but this is a matter for experiment depending on the grade of ferrite.

8.10 Pi-tank design formulae

The reactance of C1 is chosen to give a Q of 12 when the valve is working into its correct load, Rs.

$$\frac{1}{2\pi fC1} = \frac{Rs}{Q1} \qquad C1 = \frac{1920}{fRs}\ pF \qquad (1)$$

R in K ohms, f in MHz

L1 completes the first L network

$$2\pi fL1 = Rs.\frac{Q1}{Q1^2 + 1} \qquad L1 = \frac{13.3\ Rs}{f}\ \mu H \qquad (2)$$

For all practical purposes C1 and L. have the same values as would be used in a conventional tank circuit, but have reduced the required load impedance by 145 times. If this value is more than the actual 50 or 75 ohm load then it is not possible to design the rest of the network as a single L. Instead, an extra network must be used, converting the system to a pi L. This is only essential with high impedance valves like the 813, but the extra harmonic attenuation can be useful with any valve.

If all is well, L2 and C2 are calculated to transform RL to Rs ÷ 145.

$$Q2 = \sqrt{\frac{RL.145}{Rs} - 1} \qquad (3)$$

$$2\pi fL2 = Q2.\frac{Rs}{145} \qquad L2 = Q2.\frac{Rs.\ 1.1}{f}\ \mu H \qquad (4)$$

$$\frac{1}{2\pi fC2} = \frac{RL}{Q2} \qquad C2 = Q2.\frac{159}{fRL}\ pF \qquad (5)$$

note: RL in Kohm

L1 and L2 are conveniently lumped together as one coil since this gives a lower loss.

Ref: single sideband for the Radio Amateur, p.149, fifth edition,ARRL.

practical applications of pi network tank circuit for tvi reduction, G.Grammer, QST January 1952. See Appendix 4.

8.11 Rank - Bush - Murphy Television sets and 3.5MHz

"Bush TV161, TV166 and Murphy V1910, V2310 series receivers operated close to amateur radio transmitters may suffer from loss of picture during times when the transmitters are operating. The fault is caused by breakthrough of a 3.5MHz signal; the agc lead from PS1/6 in the A633 tuner unit, and its associated capacitor, resonate at this frequency and a large 3.5MHz signal is applied to the base of the rf transistor.

The fault can be eliminated by connecting a choke, Part No.CS42673, in series with the agc lead. The choke should be fitted close to capacitor 1C5" Extract from RBM Service Skill, April 1968.

8.12 spurious outputs from mixers

The chart shown as fig 8.12.1 is a convenient way of calculating the frequencies of spurious mixer outputs. The first, second, third etc. harmonics of the oscillator frequency are written down at the head of each column, and similar harmonics of the signal against each row. Each rectangle is divided in two by a diagonal line. The sum of the row and column frequencies are entered in the top triangle, and the difference in the lower. Each frequency so calculated will occur in the mixer output at some level, but those toward the top left hand corner will tend to be stronger.

The example shown is for the W6PZV transmitter on the 21MHz band. Full details can be found in the reference.

Ref: filter type 100W, output sidebander, J.Isaacs,
QST November 1962, reprinted in the fourth and fifth editions of Single Sideband for the Radio Amateur (ARRL).

Fig 8.12.1. Mixer spurious outputs resulting from 13 and 34MHz inputs. See text for explanation

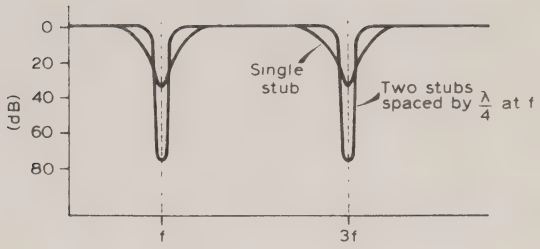


Fig 8.13.1. Attenuation of a single and double stub notch filter

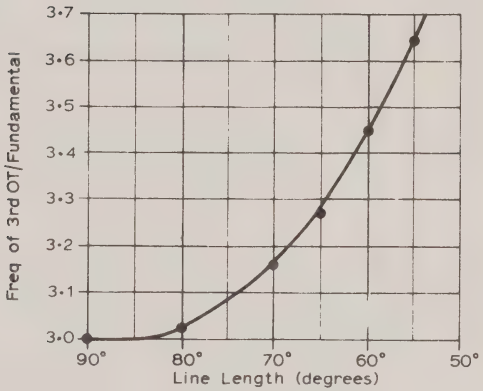


Fig 8.13.2. Relation between the frequencies of the fundamental and third overtone resonances of a capacitively loaded line. The length is shown in degrees at the fundamental; $90^{o} = 0.25\lambda$

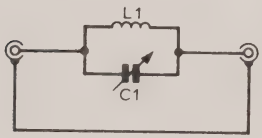


Fig 8.15.1. A wavetrap can cure mild cases of overload, and it can also be a valuable aid to diagnosis. Suggested values are C1, 75pF variable
L1 10t 16swg ½in dia 1in long for 25/70MHz
22t 24swg " " 12/35MHz

8.13 stub filters

It is well known that a quarter wavelength of feeder converts a short circuit to an open circuit and vice versa. Consequently, if an open circuit stub is connected into a coaxial feeder, at the quarter, three quarter, five quarter wave frequencies of the stub it places a short circuit across the feeder and the attenuation is very large, whilst at the half, full and one and a half frequencies there is absolutely no effect, see fig 8.13.1.

Losses in the stub limit the attenuation, but typically it is about 30dB. Two such stubs spaced by a quarter wavelength provide much more attenuation typically of the order of 80dB with narrower skirts.

Stubs can be used to notch out interference to a television set say at 145MHz, or to attenuate the harmonic output of a transmitter. Unfortunately the stub length must be exact and even if the type number of the cable is known its velocity can vary by several percent from batch to batch. The recommended method is to cut the stub a little too long and then prune a quarter of an inch at a time for best results. SWITCH OFF EACH TIME. In the absence of any other information the actual length of a solid polythene coaxial cable can be assumed to be about 66 percent of its electrical length, and 85 percent for foamed or semi air spaced. It is also possible to connect a variable capacitor across the end of a stub which is too short and tune it to the desired frequency. This also has the effect of raising the frequencies of the harmonic notches, which may be useful if it is desired to notch out 70MHz without attenuating channels 12 or 13. Details of how to calculate the quarterwave resonances can be found in chapter 7 of the Radio Communication Handbook, whilst fig 8.13.2 relates the quarter and three quarter wave frequencies of a capacitively loaded line. The quarter wave spacing of stubs is much less critical and presents no problem.

Ref: (1) curing tvi with coaxial stubs by T.N.Lloyd, G3SL, RSGB Bulletin, March 1958, see appendix 8.
(2) technical topics, Radio Communication, December 1970, see appendix 7.

8.14 table top tv aerials

These should be avoided.

Ref: an investigation into table top television aerials, M.Margolis, G3NMR. Radio Communication, September 1969.

8.15 wavetraps and notch filters

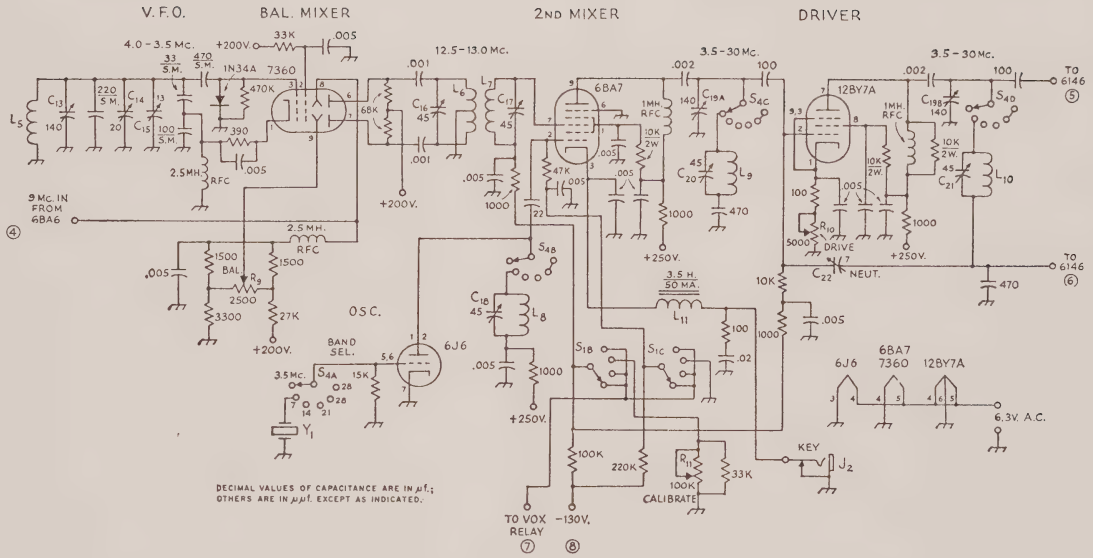
A parallel tuned circuit mounted in a tin can, fitted with coaxial input and output connectors will attenuate the frequency to which it is tuned. This can cure overload tvi but it can also be useful as an aid to diagnosis when it is not clear which frequency is causing the tvi. If interference is not in the television channel, it should be possible to tune the wavetrap to reduce it without attenuating the picture, whilst harmonics in the channel will be attenuated with the vision or sound signals. Interference not entering the set from the aerial will not be affected.

Calibration of a wavetrap covering amateur bands is quite easily done by inserting it in the coaxial cable to the station receiver and tuning for a null. For the 25 - 70MHz range, a calibrated gdo is sufficiently accurate since a wavetrap is not in any case a precise frequency meter. There is no need to worry unduly about the detuning effect of removing the can to permit the gdo to couple to the coil.

A wavetrap is rather a crude notch filter, and the null may not be very deep. It is possible to modify it to get a very deep notch at the expense of some insertion loss, which is generally insignificant in receiver applications. Such devices are the basis of the Post Office 48 series of filters and have been described in the references. It is possible to get a very deep (60dB) notch with this type of filter but adjusting the resistor and the tuning is very tedious. It is implied in the second reference that the filter is suitable for transmitter use, but as the parallel 30 ohm resistor will consume more than half the power, this is not recommended.

Ref: (1) Technical Topics, p.838, Radio Communication, December 1971, see Appendix 10.

(2) Exhibition Review, p.731, RSGB Bulletin, November 1967, see Appendix 9.



V.f.o., band-heterodyning and driver circuits. Resistances are in ohms, and fixed resistors used by the author are rated (conservatively in most cases) at 1 watt. Fixed capacitors of less than 0.001 μf. are mica or silver mica (SM); others are disk ceramic. Triode sections of 6J6 are connected in parallel.

C_{13}—Midget two-bearing 140-μμf. air variable.
C_{14}—N300 5–20-μμf. ceramic trimmer (Erie TS-D).
C_{15}—NP0 2.5–13-μμf. ceramic trimmer (CRL 822-BZ).
C_{16}, C_{17}, C_{18}, C_{20}, C_{21}—7–45-μμf. ceramic trimmer (CRL 822-BN). In band-switching circuits, a similar capacitor is connected across each coil.
C_{19}—Dual 140-μμf. air variable.
C_{22}—NP0 1.5–7-μμf. ceramic trimmer (CRL 822-EZ).
J_2—Closed-circuit jack.
L_5—26 turns No. 22 enam., close-wound on ½-inch low-loss bakelite form (National XR-50 form with slug removed).
L_6, L_7—26 turns No. 26 enam., close-wound on ⅜-inch polystyrene rod, forms mounted as described for L_1L_2.
L_8, L_9, L_{10}—See coil table.
L_{11}—Filter choke (Stancor C1080).
R_9, R_{10}, R_{11}—Linear control.
S_1—See Fig. 1.
S_4—4-pole 6-position ceramic rotary switch (CRL P-272 Index head, 4 type XD wafers).
Y_1—16.5 Mc. for 2.5-Mc. output.
20.0 Mc. for 7-Mc. output.
27.0 Mc. for 14-Mc. output.
34.0 Mc. for 21-Mc. output.
41.0 Mc. for 28–28.5-Mc. output.
41.5 Mc. for 28.5–29-Mc. output.

Chart of Harmonic Frequencies

Osc. Freq. Mc.	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4.0	4.1	4.2	4.3	4.4
I.F. (Osc. + 9 Mc.)	11.0	11.1	11.2	11.3	11.4	11.5	11.6	11.7	11.8	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	12.9	13.0	13.1	13.2	13.3	13.4
3rd Har.	6.0	6.3	6.6	6.9	7.2	7.5	7.8	8.1	8.4	8.7	9.0	9.3	9.6	9.9	10.2	10.5	10.8	11.1	11.4	11.7	12.0	12.3	12.6	12.9	13.2
4th Har.	8.3	8.4	8.8	9.2	9.6	10.0	10.4	10.8	11.2	11.6	12.0	12.4	12.8	13.2	13.6	14.0	14.4	14.8	15.2	15.6	16.0	16.4	16.8	17.2	17.6
5th Har.	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5	14.0	14.5	15.0	15.5	16.0	16.5	17.0	17.5	18.0	18.5	19.0	19.5	20.0	20.5	21.0	21.5	22.0

APPENDIX 2

EXTRACT FROM 'HARMONIC RADIATION FROM EXTERNAL NON-LINEAR SOURCES' M.Seybold, W2RYI

As usual with tvi problems, a harmonic entering a receiver at a frequency near that of the picture carrier will not produce cross-hatching unless it is at least 1/100 as strong as the tv carrier. A harmonic measuring 100 microvolts at tv aerial terminals might never be seen on a set located within walking distance of a tv transmitter. The same level of harmonic measured at a fringe area receiver, however, could very well be equal in strength to the picture carrier, and could produce cross-hatching as black and white as the picture elements. If all amateur transmitters were completely single-signal radiators, the fringe-area boys would still have more tvi problems than the amateurs in the primary coverage areas,because harmonics from external rectifiers are produced with equal facility in both areas.

Basically, any rectifier can produce harmonics if a signal is fed to the cathode-anode circuit. The low order harmonics are the strongest, and the high order harmonics become progressively weaker unless some common resonant circuit accentuates a specific multiple of the fundamental frequency. A good rectifier is one which has the largest ratio of forward to-reverse direction current flow. A device having a low rectification ratio will be less efficient as a harmonic producer, the ultimate being a pure conductor which passes current equally well in both directions, producing no harmonics, or a nonconductor which will not pass current in either direction.

Rectifiers are called nonlinear devices because of the marked discontinuity in the graphic presentation of their conduction characteristics. Triodes and pentodes are also nonlinear devices because the output is not exactly proportional to the input, and a graph illustrating the operating characteristics discloses a curved line. The range in which an amplifier is normally used is represented by such a limited portion of the curve that it is almost a straight line, and the harmonic output is extremely low. If the range is increased by applying a large input signal, the portion of the curve used no longer approximates a straight line, and the output signal, therefore, is not an exact reproduction of the input signal. The resultant wave shape is a composite of strong harmonics.

Natural born rectifiers

Nature is a prolific producer of rectifiers. Oxides and other corrosion products of metals will frequently pass current better in one direction than in the reverse. The efficiency of most of these compounds is low, but some of nature's products are excellent rectifiers.

Lead sulphide is the galena crystal of early radio fame. Silicon and germanium diodes are employed in many modern applications. Copper oxide and selenium, produced under controlled conditions, are utilized extensively for power rectification.

Because corrosion of such metals as iron, copper, and aluminium proceeds uncontrolled in nature, the rectification ability of the corrosion by-products from these metals varies immensely. If the material can pass current slightly better in one direction, however, and if it is part of a circuit arrangement in which rf signals can be admitted and released, harmonics will be produced. The strength of the harmonic is a function of the rf voltage applied, the efficiency of the rectifier, and the resonant frequency of the system.

All of the elements required to produce a harmonic generating system are present in the houses and structures in the vicinity of amateur stations. If a house could be observed with X-ray eyes, the metallic structure standing there would be identical to the conductors that a radio wave would recognise as it passes through the maze of pipes, wires, ducts, and fixtures. An rf signal produces standing waves on the various elements of this complex receiving aerial, and wherever a rusty or corroded joint has formed between pipes or lines crossing each other, rectification takes place. The harmonics produced are reradiated by the same metallic maze.

If a joint is an efficient rectifier, if the rf voltage applied is high enough, and if the resonant frequency of the metallic structure is appropriate, a nearby tv aerial may receive a harmonic signal sufficiently strong to interfere with the picture. A poker joint produced a 1000 microvolt 57-Mc signal on the feeder of a tv aerial located 30feet from the joint and 80feet from the 28.5Mc. transmitting aerial.

Because manufactured rectifiers are usually the most efficient, any equipment containing them may be suspected of producing harmonics. The access of rf signal to equipment rectifiers is the limiting factor in tvi production. Other valves, vacuum and gas, triodes and pentodes, can also produce harmonics if sufficient rf reaches them in the equipment suspected.

The table lists some of the places where trouble may be encountered. Locating natural nonlinear joints is sometimes difficult. Watching the interference pattern on a tv receiver while pushing exposed pipes, air ducts, BX cables, etc., may disclose the location of a joint. The intensity of the interference changes rapidly as the joint is jarred by pushing the pipe or pounding the floor or wall behind it.

Nonlinear Systems

Manufactured:

Amplifiers	Fluorescent lamps	
Battery chargers	Hearing aids	Power supplies, regulators
Diode probes	Intercoms	Radios
Electronic control devices	Modulation indicators	TV receivers
Field strength meters	Neon bulbs	Toy trains (dc)

Corroded joints in conjunction with:

Air ducts
Bathroom, kitchen and laundry fixtures and equipment
Ceiling and wall fixtures, chandeliers
Chains
Conduits
Furnace and hot water installation
Ground clamps; power line, telephone, radio, tv
Gutters and roof drains
Guy wires and lanyards
Lightning arrestors and lightning rods
Metal fences
Metal mesh lath for plaster and stucco
Metal towers and masts
Outside power and telephone lines and equipment
Pipes; gas, steam, water, sewer, and vents
Radiators and registers
Receiving antennas radio and tv
Reinforcement rods in concrete
Telephone installation
Thermostat system
Transmitting antennas
Sheet metal roofs and structure
Stove pipes
Structural steel beams and framework
Wiring; bell, intercom, power and light

APPENDIX 3

MODIFICATIONS TO REDUCE OSCILLATOR RADIATION FROM THE HRO RECEIVER

The following recommendation for reducing oscillator radiation from the HRO receiver came from G8AGM.

1. Decouple the following points to chassis with 560pF disc ceramics with minimum lead length:

   (a) both heater pins of oscillator valve

   (b) both heater pins of mixer valve

   (c) both loudspeaker terminals at points of exit from cabinet

   (d) all three power supply leads points of exit from cabinet

2. Replace lead to oscillator top cap with 4in length of 75ohm ¼in coaxial cable, earthing braiding at end remote from valve. (This necessitates retuning oscillator slightly).

3. Ensure both oscillator and mixer valves are fitted with screen can and cap.

This sort of treatment may be useful on other receivers where local oscillator radiation is a problem.

APPENDIX 4

EXTRACT FROM 'BY-PASSING FOR HARMONIC REDUCTION'
G.Grammer, W1DF

The curves of Figs 1 and 2 show the results of measurements made on various types of mica condensers. Curves A and B in Fig 1, and curve A in Fig 2, were obtained by making the connections between the condenser terminals and a metal plate just as short as was physically possible. The postage stamp micas in curve A, Fig 2, were checked by trimming a pair of soldering lugs off at the height of the wire terminals (right at the condenser) when the condenser was flat against the plate, so that in effect the condenser was connected directly to the plate through about 3/32inch of lug. These three curves probably represent the highest resonant frequencies that it would be possible to obtain in a practical installation. The remaining curves approximate various mounting conditions that might obtain in practice. It is fairly obvious that the lead length external to the condenser is of great importance in determining the resonant frequency.

The curves are useful as a guide, but should not be taken literally to the last megacycle, because small variations in capacitance from the marked value will naturally have some effect. A number of samples of different makes were tested, and while there was some spread in the values for a given marked capacitance, the resonant frequencies actually did not vary more than 5 per cent (for a given case type) from the mean value.

An interesting point that the checks brought out was that in all cases the resonant frequency was highest when the condenser was flat against the plate, even when raising it from the plate did not change the total path length. The presence of the large metal surface close to the works of the condenser reduces its internal inductance in much the same way that a close fitting shield reduces the inductance of a coil.

Fig 3 shows the variation in reactance of a circuit series resonated at 70MHz, the geometric center of the 54-88MHz band. Several LC ratios are shown, together with the reactance of a pure capacitance over the same frequency range. The improvement resulting from using larger values of capacitance is clearly shown. The improvement in the 54-88MHz region resulting from series resonating the by-pass circuit is most marked. The reactances in the four cases indicated in Fig 3 would be approximately as follows at 200MHz:

100 uufd	series	resonant	at	70MHz	-	57 ohms
200 uufd	"	"	"	"	-	28 ohms
500 uufd	"	"	"	"	-	11 ohms
1000 uufd	"	"	"	60MHz	-	8 ohms

The last two are still pretty effective by-passes even though the frequency is far above resonance.

Disc ceramics

The high-K disc ceramics are of particular interest, because of their small size and lead arrangement, in applications within their voltage rating. As might be expected, a given capacitance in a disc condenser can be made to resonate at a higher frequency than is possible with mica units. However, the characteristics of the condensers are such that they cannot be held to as close capacitance tolerances as mica units, and the actual capacitance may deviate considerably from the marked value. For example, a batch of condensers marked 0.001 turned out, on measurement, to average about 0.002 ufd. On the other hand, a batch of 470 uufd units actually averaged the marked value. If this variability is typical, it becomes difficult to offer very specific suggestions as to sizes to use for series resonating, except that a 470 uufd disc ceramic obviously can be adjusted to resonate anywhere from 54 to 88MHz by trimming its leads to the proper length and checking with the grid dip meter.

The fact is that when miniature ($\frac{1}{4}$inch diameter) condensers of this type are used to by-pass shielded leads as described below it does not matter much whether the by-pass circuit is series-resonated or not. If the lead length is reduced to zero, which can easily be done, the path from the shield braid to the inner conductor is as good a short circuit as could be obtained by a direct connection, at any frequency of interest from the tvi standpoint, provided the capacitance of the condenser is at least 0.001 ufd.

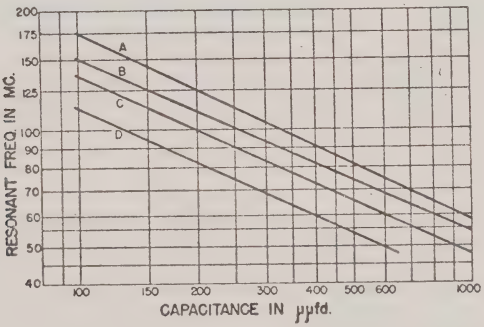


Fig. 1 — Resonant frequencies of transmitting-type mica by-pass condensers. *A* — case type CM-45 with terminals short-circuited by metal plate; *B* — case type CM-55 with terminals short-circuited by metal plate; *C* — case type CM-55 mounted with $\frac{1}{8}$-inch spacers on metal plate; *D* — case type CM-55 shorted by shielded wire approximately 0.1 inch in diameter (Belden No. 8885).

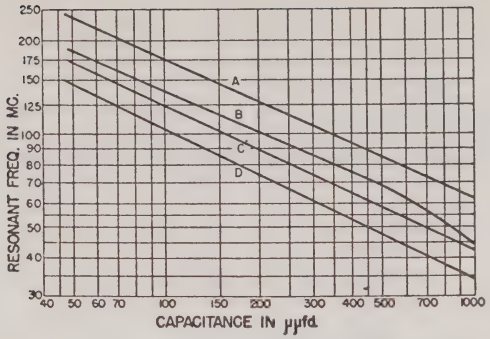


Fig. 2 — Resonant frequencies of postage-stamp mica condensers. Approximate dimensions 3/4 by 3/8 by 3/16 inches for all capacitances except 1000 μμfd., which is 3/4 by 3/4 by 3/16 inches. *A* — mounted flat on metal plate with shortest possible lug connections to wire terminals at point of leaving case; *B* — shorted by shielded wire; *C* — as in *A* at one end, but with 5/8-inch lead parallel to metal plate at the other; *D* — with 1/4-inch leads shorted by metal plate. In *B* and *D* the wire leads were bent at right angles to the flat surface of the condenser

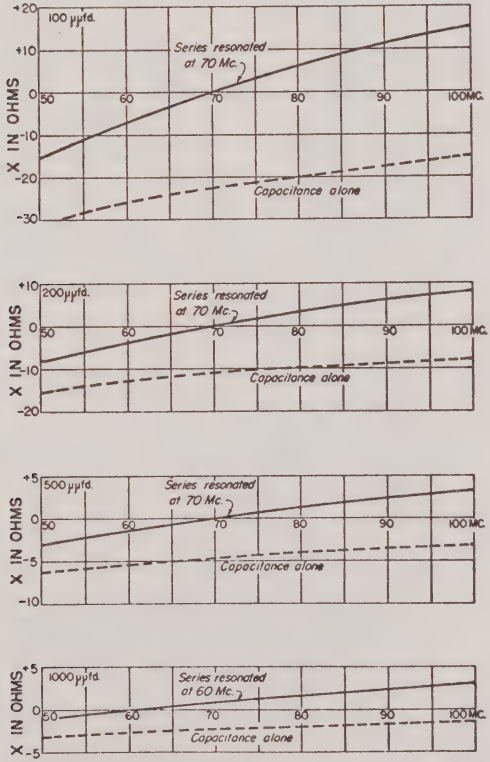
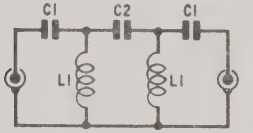


Fig. 3 — Reactance of series-resonant circuits of several *LC* ratios.

APPENDIX 5

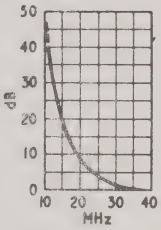
PRACTICAL DESIGNS FOR HIGH PASS AND LOW PASS FILTERS

High Pass Filters

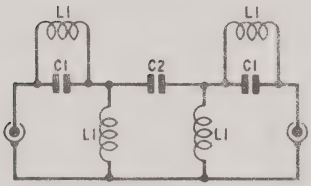


C1 ..... 100pF
C2 ..... 50pF

L1 ..... 0·28μH ..... 3 TURNS ..... 3/16" WDG LENGTH .....
INTERNAL DIA 3/4" ..... 16 SWG COPPER WIRE

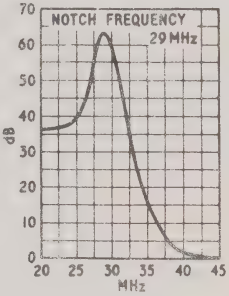


Elementary filter useful for lower frequency bands.

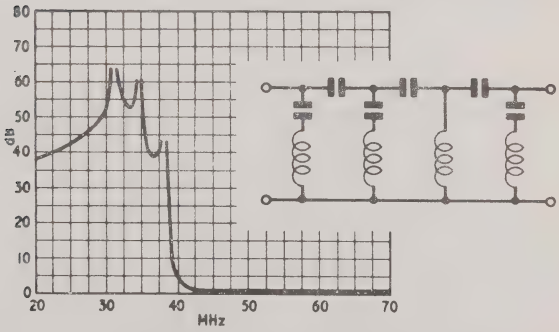


C1 ..... 100pF C2 ..... 25pF

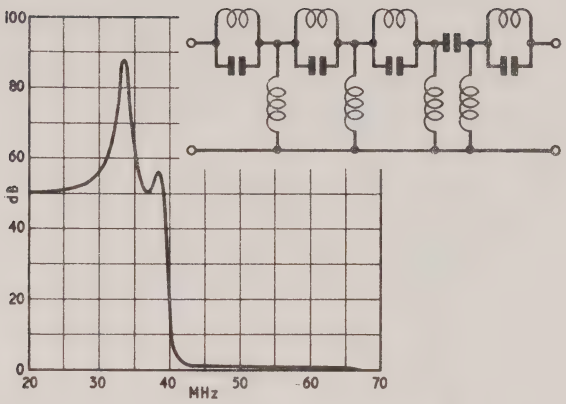
L1 ..... 0·285μH ..... 4 1/4 TURNS .....
1/4" WDG LENGTH ..... INTERNAL DIA
1/2" ..... LEAD LENGTH 3/4" .....
18 SWG COPPER WIRE



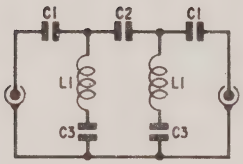
High pass filter with maximum attenuation at 29 MHz.



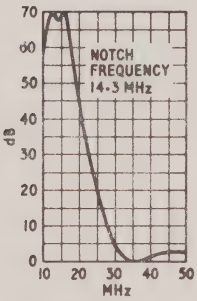
Telegraph Condenser Co filter type C 263.



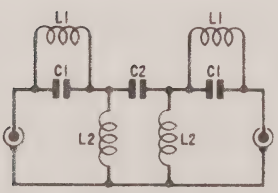
Belling and Lee filter type L 1425.

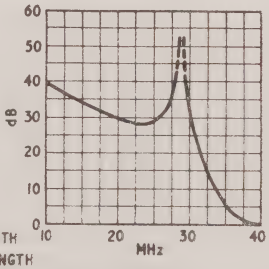


C1 ..... 71pF C2 ..... 35pF C3 ..... 520pF
L1 ..... 0·23μH ..... 7 TURNS .....
3/4" WINDING LENGTH .....
INTERNAL DIA 3/8" .....
LEAD LENGTH 3/4" .....
16 SWG COPPER WIRE



High pass filter with maximum attenuation at 14 MHz.

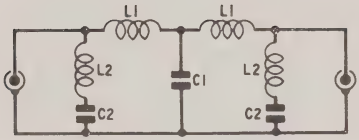




C1 ..... 100pF C2 ..... 33pF
L1 ..... 0·3μH ..... 9 TURNS ..... 1 1/4" WDG LG'TH
L2 ..... 0·2μH ..... 6 TURNS ..... 3/4" WDG LENGTH
INTERNAL DIA 3/8" ..... LEAD LENGTH 1/4" ..... 16 SWG COPPER WIRE

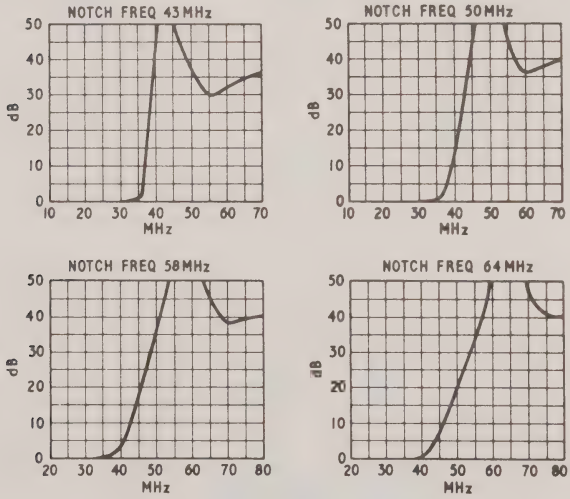
The Tobacco Tin Filter.

Low Pass Filters

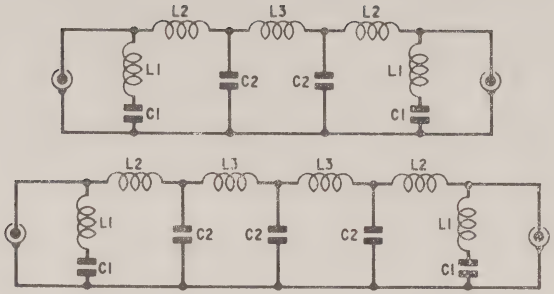


CHAN No	C1 pF	C2 pF	L1 µH	L1 TURNS	L1 WDG LENGTH	L2 µH	L2 TURNS	L2 WDG LENGTH
1	110	30·2	0·55	9	7/8"	0·44	8	7/8"
2	110	38·2	0·56	9	7/8"	0·26	6	3/4"
3 & 4	103	38·3	0·58	9	7/8"	0·2	5	3/4"
5	93·5	34·8	0·52	9	7/8"	0·18	5	1"

SELF-SUPPORTING COILS ..... INTERNAL DIA 1/2" ..... LEAD LENGTH 1" .....
16 SWG COPPER WIRE



A single channel low pass filter in four versions.



C1 ..... 36pF C2 ..... 120pF

L1 ..... 0·36μH 7 TURNS 1" WINDING LENGTH

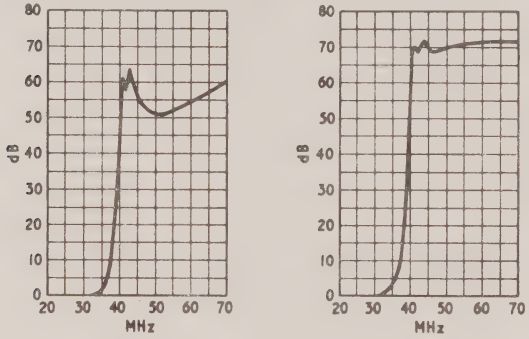
L2 ..... 0·59μH 10 TURNS 1" WINDING LENGTH

L3 ..... 0·73μH 12 TURNS 1-3/16" WINDING LENGTH

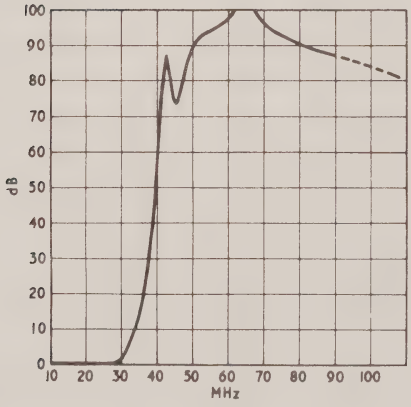
SELF-SUPPORTING COILS ..... I/D 1/2" .....

LEAD LENGTH 1" .....

16 SWG COPPER WIRE



Two M derived filters useful on all channels.



Miniature Electronic Developments Co filter type FL75A.

APPENDIX 6

EXTRACT FROM 'A SENSITIVE HARMONIC INDICATOR'
J.W.Mathews, G6LL

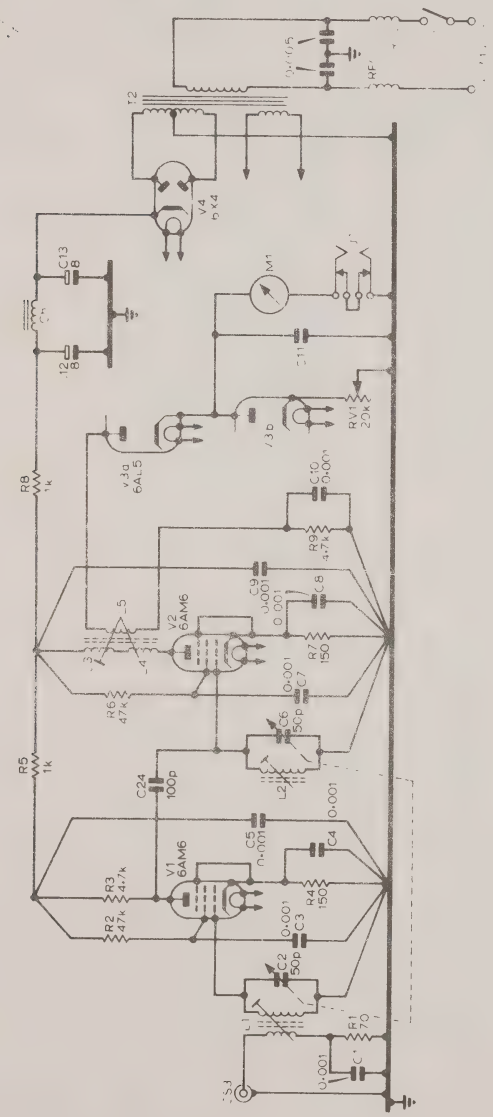


Fig 1. Circuit diagram of the sensitive harmonic indicator. All fixed resistors are ½watt rating. The mains transformer is 250-9-250V 25mA. 6.3V 2A and the smoothing choke CH, 10H. The meter M1 is 0.100uA full scale deflection

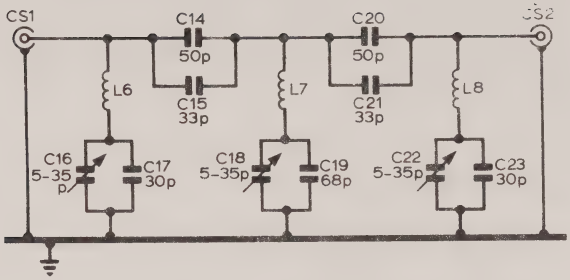


Fig 2. Circuit of high pass filter desirable to reduce possibility of overloading the first rf stage at the fundamental frequency of the transmitter

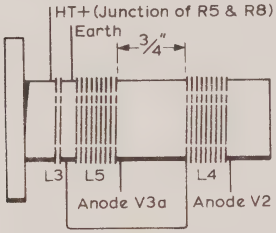


Fig 3. Details of the bandpass transformer L3, L4, L5. See the Coil Table for winding information

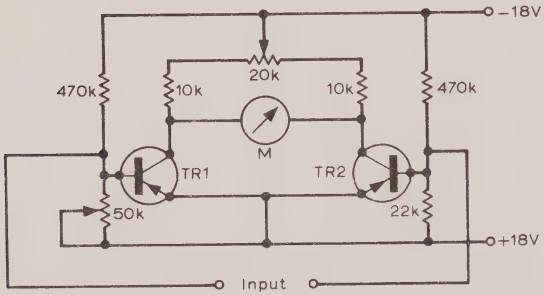
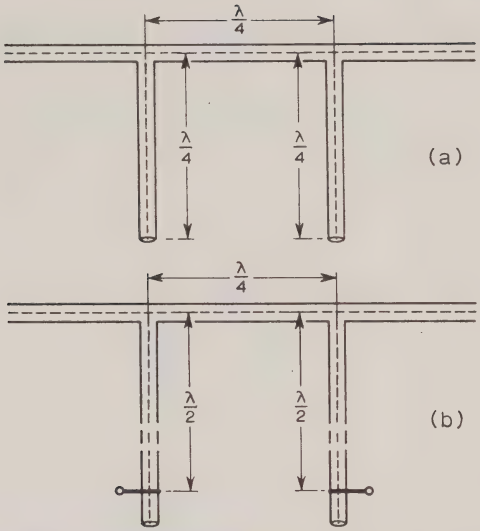


Fig 4. Transistor dc amplifier to enable a 0.1mA meter to be used in place of the 100uA instrument specified

APPENDIX 7

TWO STUB FILTERS



Two stub filters capable of providing a notch of about 70 or 80dB at centre frequency. (a) is the open-circuited quarter-wave stubs; (b) the G8ANQ version using short-circuited half-wave stubs with moveable "pin" short-circuiting device

APPENDIX 8

CURING TVI WITH COAXIAL STUBS, T.M.Lloyd, G3SL

The purpose of this article is to describe a method of curing tvi with coaxial stubs and also a method of cutting such stubs to resonate at the centre frequency of the band to be suppressed.

The transmitter at G3SL is a G5RV type using a single 807 in the pa with a pi-network output circuit. The transmitter feeds an all band dipole via a three section filter and a 72ohm coaxial cable. There is no aerial tuning unit. Using this arrangement it was found that heavy interference was caused to the BBC Channel 1 sound and vision. It was obvious that something more effective was needed to suppress the harmonics occurring in the band 42-45MHz.

It occurred to the writer that a stub made of coaxial cable could be used to short circuit effectively such harmonics. A line, whether coaxial or otherwise, has a characteristic impedance which is determined by its physical dimensions and the dielectric constant of the insulating material. When terminated by an impedance equal to its characteristic impedance, all the energy is absorbed in the load. When terminated by any other value of impedance, some energy is reflected back to the source. The greatest possible deviation from the characteristic impedance at the termination must be the conditions of minimum and maximum impedance, ie, short circuit and open circuit. Under these conditions, the maximum amount of energy is reflected back to the source.

There must be points along the line where the reflected energy is opposing the energy travelling towards the load, and if the reflected energy can be of sufficient magnitude, the cancellation will be complete, except for slight losses in the line. At the points where the voltages cancel, a very low impedance exists ie an effective short circuit. This condition will recur at intervals of a quarter wavelength, but here it should be noted that owing to the change of velocity in the cable, the actual length will be less than a quarter wavelength in free space. The velocity constant of the particular cable in use will determine the actual length needed to represent a quarter wavelength.

A quarter wavelength of line open circuited at one end will appear to be almost a short circuit at the other end. On the other hand, a quarter wavelength of line short circuited at one end will appear to be an open circuit at the opposite end. For any length other than a quarter wave (or multiples thereof) the line will look reactive, being resistive at the exact quarter wavelength points.

The coaxial stub

The stub used by the writer is a piece of coaxial cable with an open circuit at its free end, cut to an exact quarter wavelength at 43MHz so that a very low impedance appears at the other end. This low impedance is put across the feeder at the transmitter output to act as a bypass, thereby preventing harmonic energy travelling up the feeder to the aerial and so being radiated. A Belling-Lee coaxial plug is fitted at the end to be connected to the transmitter, while the other end of the cable is trimmed to avoid stray ends of the braiding shorting to the inner conductor. As a further precaution, it is dipped in polystyrene cement to seal the end, in use the stub dangles down the rear of the table on which the transmitter stands.

The first stub was constructed of solid polythene dielectric coaxial cable known as Uniradio 70 (BICC T3022). It has an impedance of 72 ohms a velocity constant of 0.67, and capacity of 22pF per foot. The inner conductor consists of seven strands of 0.0076in copper wire, while the overall outside diameter is 0.23in. Similar cable with the same characteristics is made by various manufacturers. The length required for channel 1 is 3ft 7in including the Belling-Lee coaxial plug.

A semi air spaced coaxial cable with sponge polythene dielectric, manufactured by Aerialite Limited under the code number 2695/4493, has also been tried. This has an overall diameter of approximately 0.21in and an inner conductor of seven strands of 0.01 in copper wire. The length required with this type of cable is 4ft 6½in including the plug on the end.

The arrangement in use before the installation of the stub is illustrated in fig 1(a). From the modified arrangement in fig 1(b), it will be seen that the 5pF capacitor coupling the harmonic check point to the output socket has been removed and the two sockets connected in parallel. These sockets are strapped with a piece of 14 swg tinned copper wire about ½in long. It is important that this connection should be made as short as possible - if necessary a new socket should be installed for the stub, which can then be plugged in parallel with the feeder where it emerges from the transmitter.

The sub acts as a suppressor for a band of frequencies centred on 43MHz, but at the frequencies of the amateur bands (1.8 to 30MHz) the stub is much shorter than a quarter wavelength and adds only a little capacity to the pa output circuit, which results in a slight change in the tuning point to restore resonance.

As coaxial cable has a velocity constant of less than one the physical length of cable required is less than that of a quarter wavelength in

free space, as mentioned earlier. If cable other than the type described above is used, the following procedure should be adopted to cut it to the exact length.

Adjusting the stub to length

The test equipment required for accurately adjusting the length of the stub is a calibrated signal generator covering 43MHz and a valve voltmeter complete with diode probe. The equipment is connected up as shown in fig 2(a) with the signal generator adjusted to give maximum reading on the valve voltmeter when tuned to 43MHz; the cable is connected in parallel with the diode probe with the shortest possible connections. It is best to start with about 5ft. Pieces are then snipped off the free end of the cable while watching the valve voltmeter reading. It will soon be noticed that the reading falls as the correct length is approached. Before it has fallen to zero the frequency of the generator can be rocked to find the exact frequency and in this manner the tuning can be followed 'up the dial' as it were as the last few pieces are snipped off.

Stubs made from the cables mentioned were checked with the arrangement shown in fig 2(b). These tests showed that the Uniradio 70 cable gave a high attenuation over about 10MHz from 40 to 50MHz, whereas the stub made with the semi air spaced cable had a narrower bandwidth of 9MHz between 38.5 and 47.5MHz. The tests were carried out with a 100 millivolt reading on the valve voltmeter when off tune and the limits quoted are those at which the meter readings dropped substantially to zero. Between these points an amplifier, or a much more sensitive valve voltmeter would have been needed to measure the residual output.

A list of similar cables to those tested is given in Table 1.

The "proof of the pudding"

Since the installation of the stub, tests have been made with neighbours and no interference can be detected when on either cw or telephony. It may well be that the three-section filter is not necessary now.

The cure at this station has been effected entirely by the stub at the transmitter; neighbouring receivers have not been touched in any way. It is a great relief to be able to operate at any time one chooses. The cost to G3SL was about 20p.

A short circuited stub might have possibilities if connected across the aerial input of a tv receiver for the BBC channel only. In this

condition it would attenuate signals other than those around its resonant frequency. The arrangement could not be used with multi-channel receivers employing a single feeder for Bands 1 and 111.

TABLE I

A selection of co-axial cables with the same velocity constant (0·67) as Uniradio 70. The length of a quarter-wave stub of all these types should be the same as quoted in the text for Uniradio 70. All the cables listed have solid dielectric and p.v.c. outer sheaths except Uniradio 56 which has a polythene sheath.

Uniradio No.	Inner Conductor	Characteristic Impedance Z_o	Overall Diameter	American Equivalent
31	1/029	91 ohms	0·405 in.	—
32 *	—	—	—	—
39	1/036	69 ohms	0·310 in.	RG39U
43	1/032	52 ohms	0·200 in.	RG29U, RG55U, RG58U
54	7/0076	72 ohms	0·325 in.	—
56	1/022	71 ohms	0·230 in.	—
57	1/044	75 ohms	0·405 in.	—
67	7/029	52 ohms	0·405 in.	—
70	7/0076	72 ohms	0·23 in.	—

* All characteristics the same as Uniradio 70 except that Uniradio 32 has a single strand inner conductor.

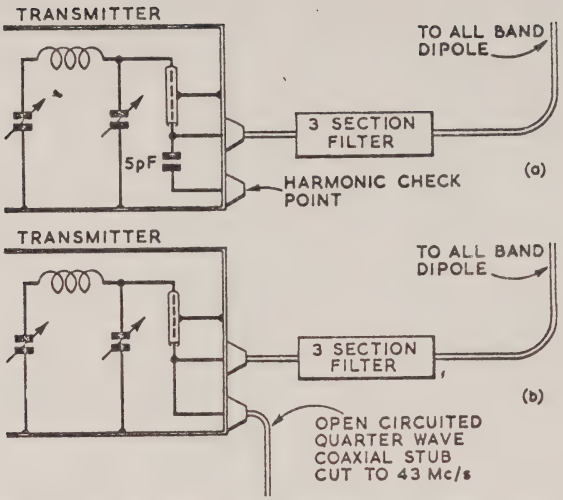


Fig. 1. (a) Original arrangement of the transmitter output at G3SL.
(b) Installation of the co-axial stub.

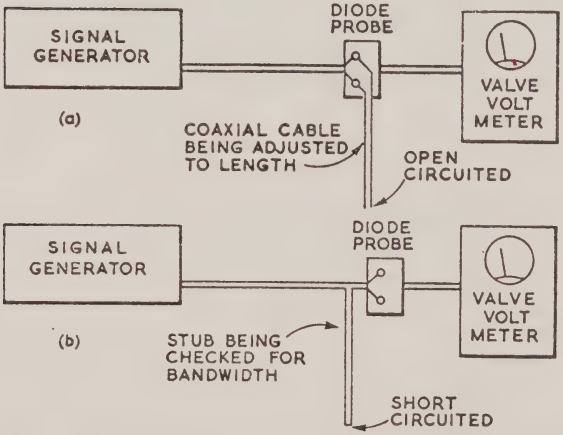
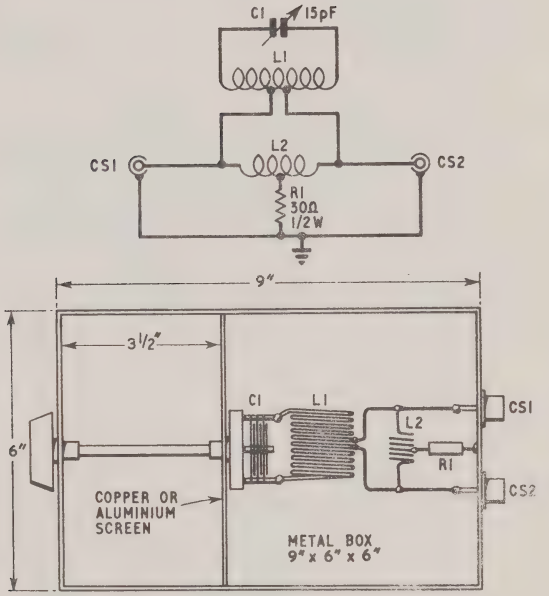


Fig. 2. Methods of adjusting co-axial stubs and checking their bandwidth.

APPENDIX 9

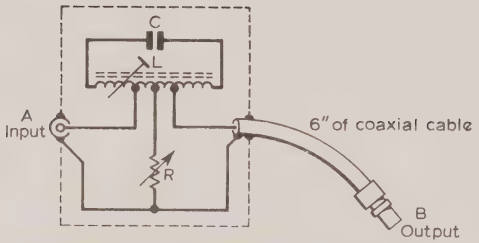
A 26 TO 60MHz NOTCH FILTER



It is built into a metal box 9 in. × 6 in. × 6 in.; R, 30 ohm, ½ watt; C, 15 pF variable; L1, 10 turns, 12 s.w.g., 1⅜ in. mean diam., 1¾ in. long, tapped at 4½ and 5½ turns; L2, 6 turns, 18 s.w.g., ½ in. diam., ¾ in. long.

APPENDIX 10

A BRIDGED-T FILTER



Post Office bridged-T filter originally designed for rejection of Sporadic-E interference on 49·75MHz but useful also as a bandstop filter in circumstances where a high-pass filter can be used to reduce tvi. In the original design : C, 27pF ; L, 12 turns 20swg, 0·8in length, 0·4in outer diameter, tuned by brass slug. For optimum rejection R is equal to Q/(4ωC), or approximately 150Ω ; A, coaxial socket ; B, coaxial plug

APPENDIX 11

THE INVESTIGATION BY THE UK POST OFFICE OF RADIO AND TELEVISION INTERFERENCE FROM AMATEUR TRANSMITTING STATIONS

Since the circumstances in which interference may occur vary a great deal, it is impracticable to lay down hard and fast rules for dealing with it, but the following paragraphs summarize the general action taken by the Post Office when it receives a complaint that radio or television reception is suffering interference from an amateur's transmissions.

Initial action

Before the Post Office will accept a complaint of interference it requires from the person complaining either evidence of the source of interference or a record of the times at which the interference occurs over a period of two weeks. Where amateur interference is occurring it may well be that the person complaining can identify the amateur by hearing his call sign. The Post Office also expects the person complaining to have, or to equip himself with, a receiving installation of a reasonable technical standard. This normally means a receiver of ordinary commercial standard and an efficient aerial of a type needed to give adequate reception in the particular situation. The Post Office may tell the amateur at the outset, possibly by telephone, that a complaint has been received, in case he wishes to avoid neighbourly friction by ceasing to transmit on a certain band during, say, evening viewing hours.

Detailed investigation

The aim is that a detailed investigation of the interference should be made as soon as possible after the complaint has been received. Since there are many different ways in which an amateur's transmissions may give rise to interference, tests have to be made to establish the mechanism by which the interference is occurring, the cure, and the responsibility for clearing the interference. This calls for the co-operation of the amateur and the people affected and the work has normally to be done in the evenings. This part of the investigation usually takes some time, bearing in mind the many calls upon the Post Office interference service and it may be hampered by the attitude of the parties to the case. Not infrequently, people complaining of amateur interference simply want the amateur closed down permanently and are most unwilling to accept that the trouble may lie in their own receiving installations. It is, unfortunately, Post Office experience that delay is sometimes caused by the failure of an amateur to deal promptly or effectively with trouble in his own equipment. If the investigation officer has reasonable grounds for thinking that an amateur's transmissions are causing interference, particularly where a number of people are affected, he may instruct the amateur to cease using specified amateur bands between certain hours pending detailed investigation.

This is done by the most practicable means available. Usually it is during a visit to the amateur, but it may sometimes be done by letter or telephone. However, any oral instruction restricting the amateur's operations is confirmed in writing.

The investigation officer examines the transmitter and other equipment with the amateur to see if the interference is caused by such things as over-modulation or the generation of harmonics or spurious emissions, and, if so, whether the interfering signals are propagated by direct radiation or over the mains wiring. Assistance may be given in locating the stage in which unwanted signals are being generated and advice about dealing with the matter, but the responsibility for finding out what is wrong and what is the remedy lies with the amateur and modification must be made by him. The amateur is asked to let the investigation officer know when the modifications have been made, and is instructed, with confirmation in writing, not to use the transmitter in the meantime during sound broadcasting or television hours as the case may be. If tests with the investigation officer show that the modifications have been successful, the amateur may be allowed, with confirmation in writing, to resume normal working.

When it has been checked that the interference is not being caused by the condition of the amateur transmitter or the way in which it is being used and the receiving installation affected is of a reasonable technical standard, investigation is made at the receiving installation. The interference may occur for a number of reasons; for example, blocking, cross-modulation, i.f. breakthrough or image effect. If reasonable remedial action, such as the fitting of a filter in the aerial lead, can be demonstrated by the investigation officer, then the responsibility for abating the interference lies with the set owner, who is advised in writing to obtain a similar filter from his radio dealer or from the manufacturer of his set. A calendar month is allowed for him to obtain a filter, during which the amateur is instructed, with confirmation in writing, not to use the frequency band(s) in question during sound broadcasting or television hours as the case may be. At the end of the calendar month the amateur may be allowed to resume transmissions whether or not a filter has been fitted to the receiver. It may sometimes be possible to leave a demonstration filter in position for a trial period during which the amateur transmits normally, if so, he is advised to this effect, with confirmation in writing. It has been found that the amateur himself sometimes provides a filter or other remedy to ensure an amicable settlement.

With superheterodyne broadcast receivers it may be possible to tune an amateur's transmissions in and out from one end of the receiver tuning scale to the other. Provided that reception of the local BBC station is not affected, the case is not treated as one of interference.

Occasionally amateur transmissions are picked up by some electrical apparatus, such as a tape recorder or public address system, or by a wired television system. Provided tests show that the amateur is operating within the terms of his licence, the Post Office does not give protection to the apparatus in question, and action is normally limited to giving advice on means of reducing the susceptibility of the apparatus to interference.

APPENDIX 12

LIST OF SUGGESTED EQUIPMENT FOR A TVI GROUP

Essential

Good low pass filters for 52 and 75ohms, with a deep notch at the local band 1 television channel, preferably with air spaced capacitors to withstand high swr.

A good high pass filter with notches at 29, 21 and 14MHz. (not TCC/GPO 38A)

Made up braid filters suitable for the area.

Coaxial tee junction box and stubs for 70 and 144MHz

Calibrated wave traps for say 12-35 and 25 - 70MHz enclosed in metal boxes, fitted with television coaxial sockets.

A quantity of coaxial cable - 52 and 75ohms - with connectors and adaptors as necessary.

Desirable

Low or band pass filter for 145MHz with high attenuation at 192MHz and above.

Hf band aerial matching unit

A screened dummy load. (A 110V 150W lamp in a large metal can fitted with a coaxial socket will serve if nothing better is available)

Search loop (as fig 3.1) and suitable television set.

Filter alignment generator (fig 8.6.2)

Useful

Pair of 28 or 144MHz walkie-talkies (tvi proof!)

Copy of "Simplified Modern Filter Design" by P.R.Geffe, Iliffe.

Oscilloscope suitable for modulation checking.

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